DETERMINATIVE MINERALOGY

WITH TABLES

FOR THE DETERMINATION OF MINERALS BY MEANS OF THEIR CHEMICAL AND PHYSICAL CHARACTERS

BY

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PREFACE

THE present edition differs from the first chiefly in the full restatement with each section of the tables of the classificatory characters and tests leading up to it. This adds much to the convenience of the tables for reference, since the complete description of a mineral, both physical and chemical, will now be found at one place. The supplementary tables at the end have also been adapted to a wider use by the inclusion of specific gravity and composition, in addition to luster, crystallization, and hardness; so that they may be used for the rapid determination of minerals by means of their physical properties, even in the absence of crystals.

Several more delicate tests that have been introduced in both the text and the tables will aid in the detection of minute quantities of an element or in making distinctions that are usually difficult and unsatisfactory. Among the former may be mentioned the purple of Cassius test for gold, the reduction of tungsten compounds on aluminum, and the ruby bead for copper and tin. The distinction of aragonite from calcite by means of cobalt nitrate solution is an example of the latter type, while the beautiful dimethylglyoxime test for nickel falls into both categories, since it serves not only for the recognition of nickel compounds in the presence of cobalt, but also for the detection of minute traces of nickel. The reduction of cassiterite through the action of nascent hydrogen is also a simple and thoroughly conclusive test for a mineral that often proves troublesome to the beginner.

Minor corrections and revisions have been made in many places and somewhat more specific instructions have been added concerning manipulation in the use of some of the tests; as, for example, the reduction of metals on charcoal, page 14.

While the adoption of uniform laboratory methods in different institutions is scarcely to be expected, even if desirable, it is believed that the rules and suggestions inserted on pages 62 and 65*a* may prove serviceable. They are based on many years' experience in trying to develop in the immature student habits of neatness, orderliness, and accuracy, and at the same time to inculcate a certain respect for mineral specimens, both in the laboratory and in the field.

This book has been designed for the use of students in determinative mineralogy and also to meet the needs of the geologist and the mining engineer. The tables give the physical and chemical properties of 380 minerals (100 to 150 more than the current text-books), while the arrangement is such that unknown minerals may be determined quickly and easily. The names are printed in three sizes of type intended to suggest some idea of their relative importance. Species that have been omitted are very rare and, from the practical point of view, of no importance.

Chemical composition is the most fundamental property of a mineral; and many species, particularly among the ores, can be determined with certainty only by means of chemical tests. The diagnostic value of physical characters is fully recognized, however, and the supplementary tables at the end are based entirely on these properties. The general plan of the Brush-Penfield tables has been followed, in the main, as these followed the earlier tables of von Kobell; but with much condensation and simplification of procedure and much rearrangement, particularly among the non-metallic minerals.

Chemical formulas and descriptions of physical properties have been revised thoroughly and several new species have been added. In order to simplify the procedure and facilitate the use of the tables the more difficult and elaborate tests have been avoided, and blowpipe or " dry " tests have been preferred, in general, to those made in the " wet " way.

It is intended that the use of the tables should not only furnish a name by which an unknown specimen may be called, but should also lead the student to acquire for himself a knowledge of what the mineral really is, both chemically and physically. The constant use by the student of a good treatise on descriptive mineralogy is strongly recommended. In order to facilitate such use page references to Dana's " System of Mineralogy " (6th edition) and to Dana's " Textbook of Mineralogy " (new edition) are inserted after the name of each mineral, these works being designated respectively by the initials " S " and " T."

I wish to acknowledge my indebtedness to many of my fellow instructors, of whose kindly criticism and helpful suggestions I have been glad to avail myself in the preparation of this revised edition.

J. VOLNEY LEWIS.

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DETERMINATIVE MINERALOGY

APPARATUS

Blowpipe. The ordinary brass jeweler's blowpipe, 10 or 12 inches long, serves very well. The more expensive instrument with a platinum tip is more durable. In either case it is essential that the tip shall be perforated with a very small, smooth hole.

Lamp. (*a*) The ordinary Bunsen gas burner (Fig. 10), with a tube to be inserted for blowpiping (Figs. 2–6). The tube is flattened to a narrow slit at the top and cut off slanting, with or without projecting points to form a rest for the blowpipe tip. (*b*) A lamp to use olive oil or other vegetable oil, or (*c*) one using tallow, paraffin, or other solid fuel. The last is most convenient for portable use. It is lighted with a match and the flame is then blown steeply downward for a few seconds in order to melt some of the fuel next to the wick. The heat of the flame then keeps it going. (*d*) Ordinary candles (preferably large and of tallow) serve very well. In heating a test tube with a luminous flame the tube should be held entirely above the luminous part, in order to avoid blackening it with a deposit of soot; or an alcohol lamp may be provided for this purpose where gas is not obtainable.

Forceps. For most purposes plain iron forceps, 4 or 5

inches long and filed down to small points, can be used. Those with platinum points are better but expensive.

Charcoal. Best from soft wood (willow, pine, etc.). Convenient sizes, about $\frac{1}{2}\times1\times4$ inches, may be purchased. Used as a support in many operations with the blowpipe (Figs. 5, 6), and in making reductions the carbon assists the flame.

Platinum Wire. A thin wire (24 or 25 B. & S. gage, 0.4 or 0.5 mm. diameter) about 3 inches long and sealed in a small glass tube for a handle (Fig. 9). Most used with a circular loop, $\frac{1}{8}$ inch (3 mm.) in diameter, at the end to hold a bead of borax, s.ph., or other flux.

Open and Closed Tubes. To be made of "combustion" tubing about $\frac{3}{16}$ inch internal diameter. For open tubes cut with a file into 4-inch lengths and use either straight, or better, with a bend near one end (Fig. 8), which may be made by heating until the glass is soft. For closed tubes (Fig. 7), cut into 5- or 6-inch lengths, heat the middle in the Bunsen flame or blast lamp, turning slowly in order to heat all sides alike; when soft pull quickly apart. Hold the tapering part of each tube thus formed in the flame and pull away the slender glass tip.

Hammer. Any small hammer will serve. For the special hammer, a wire handle is best.

Anvil. Any smooth flat block of iron or steel. The flat side of a hammer is good.

Magnet. A magnetized knife blade or chisel or a small horse-shoe magnet.

Blue and Green Glass. Two pieces of each, 2 or 3 inches square, for observing flame colors.

Test Tubes. Good sizes are $4\times\frac{1}{2}$ and $5\times\frac{5}{8}$ inches.

Test Tube Holder. Of brass wire or wood best—for holding hot tubes.

Streak Plate. Unglazed porcelain; a convenient size is $1\frac{1}{2}\times3$ inches.

In addition to the above the following articles will be found convenient in the laboratory. For portable outfits they may be dispensed with.

Watch Glasses. Shallow, 2 inches in diameter.

Test Tube Support. Wood, with several holes larger than the tubes. Easily made.

Agate Mortar. $1\frac{1}{4}$ inches diameter or larger, with agate pestle.

Diamond Mortar. Of steel; two-piece form is best. Useful when only small particles of a mineral are obtainable.

Glass Funnel. Two inches in diameter or larger.

Filter Paper. Round and twice the diameter of the funnel.

Charcoal Brush. For removing sublimates from charcoal an old toothbrush or any stiff brush may be used; or they may be scraped off with a knife.

Gypsum Tablets. Thin paste of plaster of Paris is spread about $\frac{1}{4}$ inch thick on a sheet of glass that has been slightly oiled. While still soft cut the paste with a knife into rectangles about $1\frac{1}{2} \times 4$ inches. These are readily removed after the plaster hardens. Used for support, like charcoal, and show some sublimates better.

Porcelain Crucible. With support. Sometimes useful for burning a filter paper.

REAGENTS

To be used dry:

Sodium Carbonate, or soda, Na_2CO_3; or sodium bicarbonate, common baking soda, $NaHCO_3$.

Sodium Tetraborate, or borax, $Na_2B_4O_7 \cdot 10H_2O$.

Borax Glass may be prepared as required by making borax beads (p. 19) and pulverizing them for use as a flux.

Sodium Ammonium Phosphate, also called "phosphorus salt" and "microcosmic salt," $HNaNH_4PO_4 \cdot 4H_2O$. Loses NH_4OH and $4H_2O$ on heating, becoming *sodium metaphosphate* ($NaPO_3$, abbreviated s.ph.).

Test Papers, small strips of blue and red litmus paper and yellow turmeric paper.

Potassium Bisulphate, $KHSO_4$.

"Boric Acid Flux," 1 part finely powered fluorite (CaF_2) with 4 parts potassium bisulphate ($KHSO_4$).

"Bismuth Flux," 1 part potassium iodide (KI), 2 parts sulphur (S), and 1 part potassium bisulphate ($KHSO_4$).

Tin, foil or granulated. Scraps of tin cans or other tin plate will serve.

Occasional use will also be found for *Zinc*, either granulated or scraps of sheet metal; *Potassium Nitrate*, KNO_3; and powdered *Galena*, PbS, *Gypsum*, $CaSO_4 \cdot 2H_2O$, and *Fluorite*, CaF_2.

To be used in liquid form:

Water, H_2O, distilled or rain water is best; for most purposes any clear water that is not "hard" will serve.

Hydrochloric Acid, HCl ("muriatic acid"), for most purposes diluted with an equal quantity of water.

The acids named below are more dangerous to handle and less useful than hydrochloric:

Nitric Acid, HNO_3 ("aqua fortis").

Nitrohydrochloric Acid ("aqua regia"), 3 parts hydrochloric and 1 part nitric acid.

Sulphuric Acid, H_2SO_4 ("oil of vitriol"). In diluting add the acid very slowly to water.

Ammonium Hydroxide, or ammonia, NH_4OH.

Potassium Hydroxide, KOH ("caustic potash"). Best kept as sticks broken to short bits and placed in a well-stoppered bottle—to be dissolved in a little water as needed.

Ammonium Molybdate, $(NH_4)_2MoO_4$. Dissolve the crystals in water that has been made alkaline with ammonia. For use acidify a little in a test tube with HNO_3; the ppt. that forms is quickly cleared up by further addition of acid.

Cobalt Nitrate, $Co(NO_3)_2$. Dissolve the crystals in 10 parts of water.

Ammonium Carbonate, $(NH_4)_2CO_3$. Dissolve in water as needed.

Ammonium Oxalate, $(NH_4)_2C_2O_4 \cdot 2H_2O$. Dissolve in water as needed.

Sodium Phosphate, Na_2HPO_4. Dissolve in water.

Barium Chloride, $BaCl_2$. Dissolve in water.

Barium Hydroxide, $Ba(OH)_2$. Dissolve in water.

Silver Nitrate, $AgNO_3$. Dissolve in water and keep in a bottle of amber color or one well wrapped with opaque paper.

Potassium Ferrocyanide, $K_4Fe(CN)_6 \cdot 3H_2O$. Dissolve in water.

Potassium Ferricyanide, $K_6Fe_2(CN)_{12}$. Dissolve a little at a time in water as needed. The solution does not keep well.

Hydrogen Peroxide, H_2O_2 ("dioxogen"). The ordinary 3% solution serves. Keep in bottle of amber color or one wrapped in opaque paper.

Stannous Chloride, $SnCl_2$, when required, may be prepared by treating tin foil with HCl.

Dimethylglyoxime, $C_4H_8O_2N_2$. Dissolve in 100 times its weight of alcohol. Useful in testing for Ni.

BLOWPIPE OPERATIONS AND CHEMICAL TESTS

1. Blast. The blast of the blowpipe should not be blown from the lungs and should not interfere with regular breathing. Distend the cheeks fully and, while breathing through the nose, allow the air to escape from the mouth through the blowpipe without making any effort to blow. Before the supply is exhausted distend the cheeks again from the lungs. In this way the blast may be continued for several minutes, when necessary, without fatigue. If the blowpipe tip is in good condition the flame will be smooth, steady, and silent (Fig. 2–6).

2. Flames. A candle flame or luminous gas flame consists of 3 concentric parts (Fig. 1): (*a*) an inner cone of unburned gases; (*b*) a luminous mantle full of glowing particles of carbon, where carbon monoxide (CO) and water (H_2O) are forming by combustion; (*c*) a hot, non-luminous mantle of the products of complete combustion, carbon dioxide (CO_2) and water (H_2O) mingling with the surrounding air, and hence with an excess of oxygen. Hot fuel is in excess in (*b*), hence it is reducing in its action; the excess of oxygen makes (*c*) oxidizing. A non-luminous Bunsen or alcohol flame differs only in lacking the incandescent carbon in (*b*).

In determinative mineralogy these flames are often directed laterally or inclined downward by the use of the blowpipe. For oxidizing effects the tip should be inserted slightly into the flame, as in Fig. 2, thereby mixing more oxygen with the

gases at the base. The best reducing effect is obtained by withdrawing the tip a little from the flame and blowing very gently (Fig. 3). The flame should not be sooty, but a little luminous carbon should extend down the whole length of it.

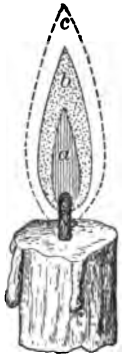

FIG. 1.

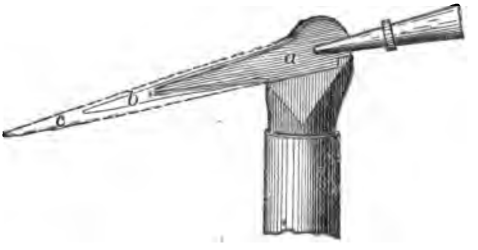

FIG. 2.

FIG. 1.—Candle flame: (*a*) Unburned gases; (*b*) burning gases, forming H_2O, CO, and luminous C; (*c*) hot combustion products, H_2O, CO_2, and O from surrounding air.

FIG. 2.—Blowpipe flame: (*b*) Intense heat and slightly reducing; (*c*) and beyond, oxidizing flame (o.f.).

3. Ignition: Fusion. The hottest flame is entirely non-luminous and the hottest part of it is just beyond the tip of the blue. The fusibility of a mineral is tested by strongly heating at this point an elongated fragment not more than 1.5 mm. ($\frac{1}{16}$ of an inch) in thickness; that is, no thicker than the "lead" of an ordinary pencil. This is held in the forceps so that it projects into the flame (Fig. 4). The mineral may fuse quietly, or with intumescence (bubbling and swelling up), or with exfoliation (splitting into leaves or flakes). The result may be a bead of colored or colorless glass, clear or filled with

bubbles; or it may be a white, opaque enamel. If infusible the mineral may remain unchanged, or it may change color,

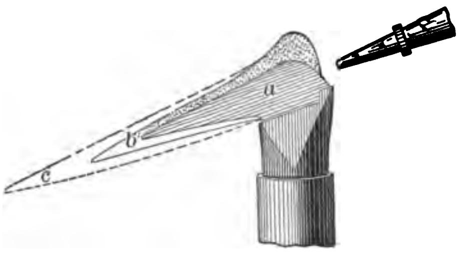

FIG. 3.—Blowpipe flame: (*b*) Strong reducing flame (r.f.), with more gas than used in o.f. and gentle blast.

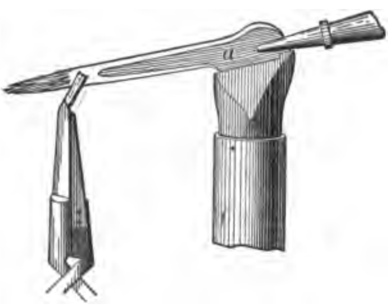

FIG. 4.—Testing fusibility, showing maximum size of fragment, manner of holding it, and position in the flame.

or become opaque, etc. All of these properties should be carefully noted.

The test of fusibility may be interfered with by *decrepitation*—the violent breaking away of particles with little crackling

explosions owing to sudden unequal heating or to the expansion of minute inclusions of water or liquid carbon dioxide. By first heating the mineral very gradually and gently in the ordinary flame this difficulty may sometimes be avoided; otherwise heat a few fragments in a closed tube until decrepitation ceases and select a fragment of suitable size if such remains. When this fails make a thin paste of the finely powdered mineral with water, spread a little of this on charcoal and heat, at first very gently, then intensely. The crust thus formed can be taken up carefully in the forceps and tested for fusibility.

4. Scale of Fusibility. The degree of fusibility of minerals is indicated by numbers referring to the following scale. Minerals named in parentheses have about the same fusibility as the standard. Comparison should be made on fragments of about the same size. Penfield recommends a standard size of about 1.5 mm. in diameter, as explained above. With the more difficultly fusible minerals, however, a much smaller fragment with a very thin edge or fine point should be tested before deciding that it is infusible.

SCALE OF FUSIBILITY

(Penfield's modification of von Kobell's scale)

1. *Stibnite*, Sb_2S_3. Fragments larger than standard size fuse easily in a luminous flame; fuses easily in closed tube below red heat. (Realgar, orpiment, sulphur.)

2. *Chalcopyrite*, $CuFeS_2$. Standard size fragment fuses in luminous flame; small fragment fuses in closed tube at red heat. (Galena, arsenopyrite, apophyllite.)

3. *Almandite* (Garnet), $Fe_3Al_2(SiO_4)_3$. Standard fragment fuses readily to globule with blowpipe; only thinnest edges rounded in luminous flame. (Malachite, wernerite, stilbite.)

4. *Actinolite*, $Ca(Mg,Fe)_3(SiO_3)_4$. Edges easily rounded on standard fragment; fine splinter fuses easily to globule. (Tremolite, wollastonite, barite.)

5. *Orthoclase*, $KAlSi_3O_8$. Edges of standard fragment rounded with difficulty; only finest splinters fuse to globule. (Sphalerite, biotite, scheelite.)

6. *Bronzite*, $(Mg,Fe)SiO_3$. Only finest points and thinnest edges can be rounded at all. (Enstatite, calamine, serpentine.)

5. Flame Color. On ignition in the forceps, and sometimes also on the charcoal, a distinct color may be imparted to the flame by the volatilization of a minute quantity of the mineral. The color is seen best against a dark background, such as a piece of charcoal or a book cover, or in a dark room. It is often more distinct when a trace of the fine powder is introduced into the flame with a clean platinum wire. (To clean the wire, heat it in the flame or boil in concentrated acid, if necessary, until it ceases to give a color to the flame.) The dry wire is dipped into the powder and then held in the flame. If the wire is first moistened with water a larger quantity of the powder will adhere and in some cases a better color is obtained. Dilute hydrochloric acid instead of water is sometimes an advantage. The wire should be introduced first into the cooler part of the flame, near the base, and gradually raised. Different substances will volatilize successively, as zones of higher temperature are reached.

FLAME COLORS

(For abbreviations, see page 60)

Color.	Shade.	Element.	Remarks.
Yellow	Intense	Na	Must be intense and persistent to indicate Na Invisible through dark blue glass
Red	Yelh. to orange	Ca	Often improved by moistening with HCl Green through green glass
Red	Crimson	Sr	Alkaline after ignition; so is Ca, but not Li Faint yellow through green glass
Red	Crimson	Li	Not alkaline after ignition; compare Sr Invisible through green glass
Green	Yellowish	Ba	Alkaline after ignition
Green	Yelh., pale	Mo	Not alkaline after ignition
Green	Bright, somewhat yelh.	B	Rarely alkaline after ignition. Test with turmeric paper and HCl sol. decisive
Green	Emerald	CuO,CuI	Blue, tinged with green, if moistened with HCl
Green	Pale	Te,Sb,Pb	
Green	Pale bluish	P	Often improved by moistening with conc. H_2SO_4
Green	Bluish	Zn	Usually streaks in outer part of flame
Blue	Greenish	P,Sb	
Blue	Azure	$CuCl_2$	Outer parts tinged emerald-green
Blue	Azure	Se	With characteristic radish-like odor
Blue	Pale azure	Pb	Green tinge in outer part of flame
Blue	Pale	As	
Violet	Pale	K	Purplish red through blue glass

6. On Charcoal. The length of the coal should be held in line with the flame, in order to catch any sublimate that may form; it should be also tilted toward the flame (Fig. 5). First burn a small spot on the coal with the oxidizing flame and note the color and appearance of the ash, in order to avoid confusing it with sublimates when making tests. Note also that the grain of the charcoal shows distinctly in the ash, while sublimates tend to conceal it.

A slight depression is cut in the charcoal near one end and 3 or 4 grains of the mineral (not larger than pin heads), or a corresponding amount of fine powder, placed in it. In general a gentle oxidizing flame is blown first (Fig. 6), but only for a few seconds, not allowing the blue flame to touch the mineral. Any decrepitation or deflagration (flashing like gunpowder) is noted. Odors should be sought the moment the heat is stopped, and any change in color, formation of sublimate, metal globules, or magnetic particles, observed. The oxidizing flame is then repeated with greater intensity until reaction ceases. A similar method is followed with the reducing flame (Fig. 5), and in many cases the reaction is facilitated by fusing the powered mineral with three times its volume of soda, or a mixture of soda and borax, or of soda and powdered charcoal.

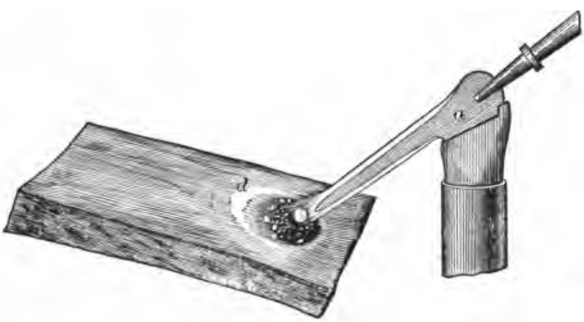

FIG. 5.—Reduction on charcoal, with sublimates (when formed) at (*d*) and beyond.

SUBLIMATES ON CHARCOAL

(For abbreviations, see page 60)

Near Assay.	Dist. from Assay.	Substance.	Remarks.
White, very volatile	Wh. to grayish	As_2O_3	Mostly far from assay; often strong garlic odor
Dense wh., volatile	Gray or slightly brownish	White, TeO_2 Gray, Te	Volatilizes in r.f., coloring flame pale green
Dense wh., volatile	Bluish	Sb_2O_3 and $SbSbO_4$	Heavy near the assay
White	White to bluish	Chlorides of Cu, Pb, Hg, NH_4, and alkalis	
Pale yel. to wh. hot; wh. cold: non-vol. in o.f.	Faint white	SnO_2	Moistened with $Co(NO_3)_2$ and ignited, subl. becomes bluish-green
Pale yel. hot; wh. cold; vol. in o.f.	Bluish	MoO_3	Touched with r.f., subl. becomes azure-blue. Cu-red MoO_2 subl. next to assay
Canary-yel. hot; wh. cold; non-vol. in o.f.	Faint white	ZnO	Moistened with $Co(NO_3)_2$ and ignited the subl. becomes green
Yel. hot; pale yel. cold; vol. in o.f. and r.f.	Dense white with bluish-wh. border	PbO $PbSO_3$ $PbSO_4$	Forms when galena and other Pb sulphides are heated very hot on charcoal
Dark yel. hot; S-yel. cold; vol. in o.f. and r.f.	Bluish-white	PbO	Heated with "bismuth flux" forms volatile yelh.-grn. subl., PbI_2
Dark orange-yel. hot; orange-yel. cold; vol. in o.f. and r.f.	Greenish-white	Bi_2O_3	Fused with "bismuth flux" in small o.f. forms yel. subl. fringed by brilliant red
Nearly blk. to rdh.-brn.; vol. in o.f. and r.f.	Yellow	CdO	Iridescent when very thin
Rdh. to deep lilac		Ag with Pb and Sb	Ag alone gives slight bnh. subl. after long ignition
Copper-red	White	MoO_2, MoO_3	Touched with r.f., white subl. becomes azure-blue
Steel-gray, faint metallic luster; very vol.	White; may be tinged red	White, SeO_2 Red, Se	Subl. colors r.f. azure-blue. Characteristic radish-like odor

6a. Reduction of Metals. Mix equal volumes of finely powdered mineral,* charcoal, and borax glass with 3 volumes of soda. Moisten slightly with water and place a mass the size of a small pea in a shallow depression on the charcoal. Fuse in a strong reducing flame for two or three minutes without interruption, unless a bead of metal becomes distinctly visible in a shorter time. If no metal is visible pry off the assay with a chisel or knife, removing with it a little of the charcoal on which it rests; grind to a fine powder in an agate mortar, and, while continuing the grinding, allow water to flow gently from the tap upon the hand and into the mortar. The surplus soda dissolves and the powdered charcoal is floated away by the overflow. Globules of metal, flattened by the grinding, will appear as bright scales on the pestle and the bottom of the mortar.

Transfer the metal to a watch glass, add a drop or two of HNO_3, warm gently and add an equal amount of water:

White Metal. Sn changes to white insoluble oxide; Pb soluble and gives white precipitate with a drop of H_2SO_4; Ag soluble and gives with a drop of HCl a white precipitate which is soluble in ammonia; Pt insoluble in HNO_3, soluble in aqua regia. Evaporate to dryness, add water and KCl, a yellow precipitate confirms Pt.

Yellow or Red Metal. Cu soluble in HNO_3 and gives reddish-brown precipitate with potass. ferrocyanide; Au insoluble in HNO_3, soluble in aqua regia. Evaporate to dryness, add a drop or two of water and a drop of dilute solution of $SnCl_2$. A violet-brown precipitate confirms Au.

7. Roasting. Spread a fine powder of the mineral thinly on charcoal and heat with a small oxidizing flame, a considerable distance beyond the tip of the blue and at no more than a dull red heat (Fig. 6). If the mineral fuses easily heat

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* If the mineral yields S, As, or Sb in o.f. on charcoal, it must first be thoroughly roasted in order to convert it into oxides.

intensely till the volatile constituents are driven off, then pulverize with a little powdered charcoal and repeat the roasting with the mixture, using the small oxidizing flame and low temperature again.

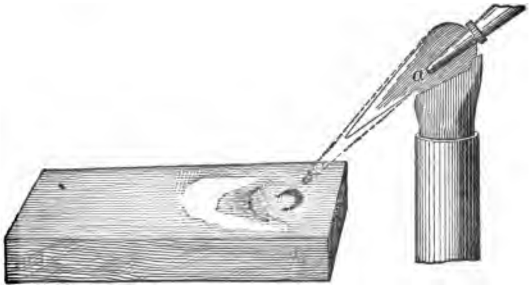

FIG. 6.—Roasting on charcoal; very small o.f., scarcely red heat.

8. On Gypsum Tablets. The tablet may be held in the same manner as the charcoal, or may be placed on charcoal as a support. A little of the pulverized mineral is fused with "bismuth flux" near one end of the tablet. Volatile iodides of the metals are

IODIDE SUBLIMATES ON GYPSUM AND CHARCOAL

(For abbreviations, see pages 59–61)

On Gypsum.	Substance.	On Charcoal.
Chrome-yel., volatile	PbI_2	Chrome-yel.; gnh. if thin; volatile
Yel. to orange; very volatile	AsI_3	Faint yellow
Orange to red; disappears in strong ammonia fumes	SbI_3	Faint yellow
Scarlet with yel.; if strongly heated is dull yel. and blk.	HgI	Faint yellow
Brownish-orange	SnI_4	White
Rdh.-brn., nearly scarlet	SeI_4	Does not show on charcoal
Chocolate-brn., with underlying scarlet; in ammonia fumes becomes orange and then cherry-red	BiI_3	Bright red; yel. near assay
Purplish-brn., darker border	TeI_4	Does not show on charcoal
Ultramarine-blue, deep	MoI_4	Does not show on charcoal

formed, many of which produce characteristic sublimates on the cool part of the gypsum. The same process may be used on charcoal, and in the table on the bottom of p. 15 the results are compared with those on gypsum.

9. In Closed Tube. The object is to heat the mineral with

SUBLIMATES IN CLOSED TUBE
(For abbreviations, see page 59)

Hot.	Cold.	Substance.	Remarks.
Cols. liquid; easily vol.	Cols. liquid	H_2O	Neutral or acid; rarely alkaline
White solid	White solid	$PbCl_2$, $SbCl_3$, As_2O_3, Sb_2O_3, NH_4 salts	
Gray metallic liquid globules		Hg	Unite by rubbing with strip of paper
Pale yel. to cols. liquid; difficultly volatile	Cols. to wh. globules	TeO_2	From Te and some compounds
Dark yel. to red liquid; easily volatile	Yel. xln. solid; pale in small amt.	S	From S and some sulphides
Dark red liquid, nearly blk.; easily volatile	Rdh.-yel. transparent solid	AsS As_2S_3	From sulphides and sulpharsenites
Blk. solid; dif. vol.	Rdh.-brown	Sb_2OS_2	Sulphides and sulphantimonites
Brilliant blk. solid; often gry. and xln. near heated end		As	From As and arsenides. Break off closed end and heat subl. for garlic odor
Brilliant blk. solid	....	HgS	Subl. rubbed gives red powder
Blk. fusible globules	....	Te	Te and tellurides; usually some TeO_2 formed (see above)
Blk. fusible globules; smallest deep red by transmitted light		Se	Often also wh. xln. SeO_2

little air, and hence with little oxidation. Use small fragments; fine powder adheres to the side of the tube and may interfere with sublimates. Volatile emanations that give an odor or condense as a sublimate or a liquid on the side of the tube are to be specially noted; also decrepitation, phosphorescence, fusion, change in form or color, or magnetism. The upper end of the tube must be kept cool, and this is best assured by holding it with the fingers only and keeping it nearly horizontal (Fig. 7).

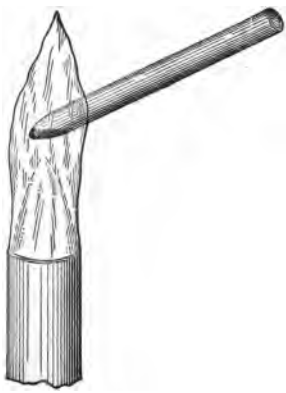

FIG. 7.—Heating in closed tube (c.t.): Hold the tube with the fingers only.

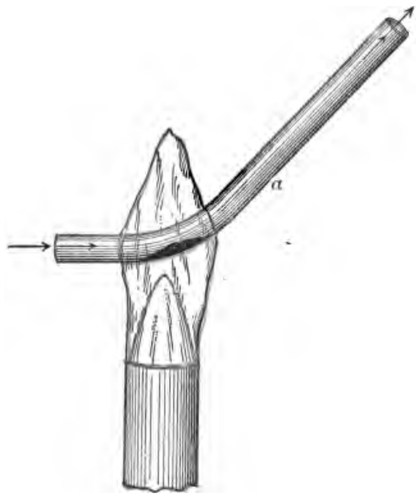

FIG. 8.—Heating in open tube (o.t.): Use tube holder and heat first at *a* to insure draft.

10. In Open Tube. The object is to heat the mineral with a good supply of air for oxidation. Place finely powdered mineral near one end of the tube (at the elbow if the tube is bent). Hold the tube steeply inclined, with the powder at the lower end, using a holder, since the whole tube will become hot. First heat the tube well just above the mineral (at *a*, Fig. 8) so as to insure a good draft, then bring the mineral over the flame. Use but little of the mineral

in order to avoid choking the tube and reducing the draft. Besides, with a large amount, volatilization may exceed oxidation and the results will be mixed and indecisive.

SUBLIMATES IN OPEN TUBE

(For abbreviations, see page 59)

Color and Character.	Substance.	Remarks.
Wh. xln., readily volatile	As_2O_3	Xln. (octahedrons) on the warm glass
Wh. xln., readily volatile	SeO_2	Us. rad. xls.; often a little red S
Wh. xln., slowly volatile	Sb_2O_3	Xls. are octahedrons and prisms
Wh. non-vol., infusible	$PbSO_3$ $PbSO_4$	Slight deposit; mostly on lower side of tube near assay
Wh. to pale yel. globules; slowly vol.	TeO_2	
Pale yel. hot; wh. cold; amorph., infus., non-vol.	$SbSbO_4$	Dense wh. smoke; subl. mostly on under side of tube; us. some volatile Sb_2O_3
Pale yel. hot; wh. cold; fus. and vol. at red heat	MoO_3	Network of delicate xls. near assay
Yel. to orange; easily vol.	S, AsS	These sublimates result from too rapid heating; will not form with proper draft and oxidation. Heat tube above assay first, then directly under it
Blk. hot; brn. cold; dif. volatile	Sb_2OS_2	
Brilliant blk.; volatile	As,HgS	
Gry. metallic globules; volatile	Hg	Unite by rubbing with strip of paper
Red, volatile	Se	Often with white SeO_2 (see above)

11. In Borax Bead. A round loop ($\frac{1}{8}$ inch diameter) of platinum wire may be made conveniently by bending it around the tapering part of a pencil near the point (Fig. 9*a*). The loop is heated in the Bunsen or blowpipe flame and dipped into the powdered borax. The part that adheres is fused to a clear globule (Fig. 10); this is again dipped into the borax, and the process is repeated until a nearly spherical bead is obtained. The hot bead is touched lightly to a fine powder of the mineral and is then heated thoroughly in the oxidizing blowpipe flame. The degree of solubility of the particles and the colors, if any, imparted to the bead are carefully noted. It is then heated continuously for some time in the reducing flame, and any change noted. The quantity of the powdered mineral in the bead is gradually increased until a distinct reaction is obtained or until the bead is saturated with it.

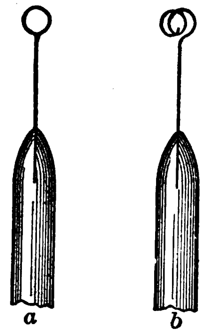

FIG. 9.—Platinum wire loops: (*a*) single loop $\frac{1}{8}$ inch, for bead tests; (*b*) double loop, holding larger quantity, for decomposing insoluble minerals in fluxes.

A *bead without a loop*, about half the size described above, may be made on the end of the wire by holding it horizontally or pointed somewhat downward in the flame. Moisten the bead with the tongue and touch the finely powdered mineral. After reducing cool the bead in the inner cone of the Bunsen flame in order to avoid oxidation.

Precaution. Sulphides, arsenides, antimonides, etc., must first be roasted thoroughly at a dull red heat (Fig. 6), as directed in Section 7, page 14, in order to convert them into oxides; otherwise no characteristic reaction will occur.

BORAX BEAD REACTIONS

(For abbreviations, see page 60)

(M indicates medium amount; + indicates much; – indicates little)

Oxidizing Flame.		Reducing Flame.		Amount.	Oxide of
Hot.	Cold.	Hot.	Cold.		
Colorless	Colorless	Colorless	Colorless	+ or –	Si, Al, Sn
Colorless	Cols. or opaq. wh.	Colorless	Cols. or opaq. wh.	+ or –	Ca, Sr, Ba, Mg, Zn, Zr, Cb
Pale yel.	Cols. or wh.	Pale yel.	Colorless	+	Pb, Sb, Cd
Pale yel.	Cols. or wh.	Gray	Gray	+	Bi
Pale yel.	Cols. or wh.	Brown	Brown	+	Mo
Pale yel.	Cols. or wh.	Yellow	Yel. to yelh-brn.	M	W
Pale yel.	Cols. or wh.	Grayish	Bnh.-violet	M	Ti
Yellow	Nearly cols.	Pale green	Nearly cols.	–	Fe, U
Yellow	Yelh.-green	Green	Green	–	Cr
Yellow	Pale yelh.-grn.	Dirty grn.	Fine green	–	V
Yel. to orange	Yellow	Pale green	Pale grn. to nearly cols.	M to +	U
Yel. to orange	Yellow	Bottle grn.	Pale green	M to +	Fe
Yel. to orange	Yelh.-grn.	Green	Green	M to +	Cr
Green	Blue	Cols. to grn.	Opaq. red (+)	– to M	Cu
Blue	Blue	Blue	Blue	– to M	Co
Violet	Rdh.-brn.	Opaq. gray	Opaq. gray	– to M	Ni
Violet	Rdh.-violet	Colorless	Colorless	–	Mn

12. In Sodium Metaphosphate Bead. The bead is made by heating sodium ammonium phosphate on a loop of platinum wire in the same manner as previously described for the borax bead; but when first fused it is much more liquid than borax and considerable care must be exercised in order to avoid

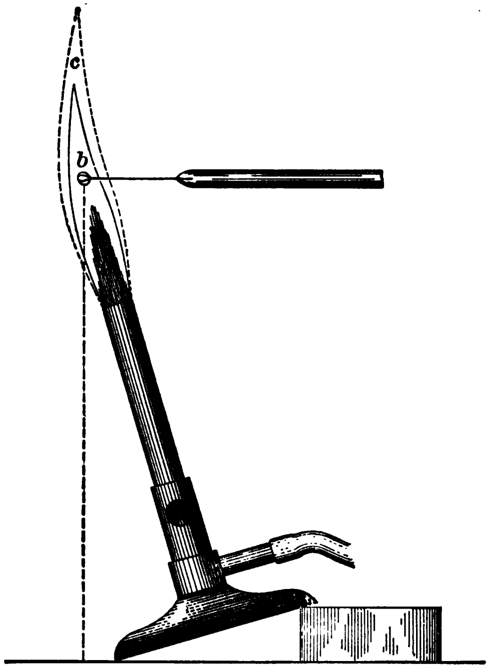

FIG. 10.—Making a bead in the Bunsen flame. If the bead drops it falls clear of the burner instead of clogging it. This position is specially important for sodium metaphosphate (s.ph.) beads.

dropping it. It is best to tilt the burner at a considerable angle (Fig. 10), so that beads cannot drop into it and clog it. Hold the wire over the center of the flame, with the circular loop horizontal. Do not undertake to fuse much of the salt

SODIUM METAPHOSPHATE BEAD REACTIONS

(For abbreviations, see page 60)

(M indicates medium amount; + indicates much; − indicates little)

Oxidizing Flame.		Reducing Flame.		Amount.	Oxide of
Hot.	Cold.	Hot.	Cold.		
Colorless	Cols. or opaq. white	Colorless	Cols. or opaq. white	− or +	Ca, Sr, Ba, Mg, Zn, Al, Zr, Sn, Si (Si nearly insol.)
Pale yel.	Colorless	Pale yel.	Colorless	+	Cd
Pale yel.	Colorless	Gray	Gray	+	Pb, Sb, Bi
Pale yel.	Colorless	Brown	Brown	+	Cb
✓ Pale yel.	Colorless	Dirty blue	Fine blue	M	W
✓ Pale yel.	Colorless	Yellow	Violet	− to +	Ti
✓ Yellow	Colorless	Pale yelh.-grn.	Colorless	−	Fe
✓ Yellow	Pale grnh.-yel.	Pale grn.	Fine grn.	M	U
✓ Yelh.-grn.	Colorless	Dirty grn.	Fine grn.	M	Mo
✓ Yel. to bnh.-red	Yel. to cols.	Red, yel., to yelh.-grn.	Nearly cols. to pale violet	M to +	Fe
✓ Yel. to deep yel.	Yellow	Dirty grn.	Fine grn.	− to M	V
✓ Red to bnh.-red	Yel. to redh.-yel.	Red to bnh.-red	Yel. to redh.-yel.	− to M	Ni
✓ Green	Pale blue	Pale yelh.-grn.	Pale blue, nearly cols.; at times ruby-red	−	Cu
Dark green	Blue	Bnh.-grn.	Opaq. red	M	Cu
✓ Dirty grn.	Fine grn.	Dirty grn.	Fine grn.	− to M	Cr
✓ Blue	Blue	Blue	Blue	− to M	Co
✓ Gryh.-violet	Violet	Colorless	Colorless	M	Mn

at a time, but build up the bead by small additions, heating each time until all bubbling stops. The salt fuses to sodium metaphosphate, $NaPO_3$, and is used in exactly the same manner as the borax bead.

13. In Sodium Carbonate Bead (Soda). The soda bead on platinum wire is opaque white when cold. It is prepared in the same manner as borax or s.ph. beads (see preceding sections), and is useful for the following reactions:

Manganese: in o.f., green when hot, blue when cold; in r.f., colorless.

Chromium: in o.f., yellow.

Quartz: in fine powder fused with about equal volume of soda gives a clear glass.

14. With Acids. For most purposes dilute hydrochloric acid is used; but for sulphides and arsenides, which require oxidation, nitric acid is best.

Usually the object of the first test with an acid is to determine whether the mineral is decomposed or dissolved by it. This is best done with a very small amount of the fine powder, just enough to be distinctly visible in the bottom of the test tube. Fill the tube with acid to a depth of $\frac{1}{2}$ to $\frac{3}{4}$ of an inch. If no immediate reaction occurs, heat to boiling and observe any change, particularly whether any of the powdered mineral has disappeared. If the mineral seems unchanged continue the boiling for several minutes. If solution or any other reaction occurs, add a larger amount of the powdered mineral in order to get distinct results.

(1) Solution may occur with effervescence in cold acid or only on heating, with the evolution of CO_2, colorless and odorless, from carbonates; H_2S, colorless and disagreeable odor, from some sulphides; Cl, nearly colorless, pungent odor, bleaches moist litmus paper, from some higher oxides in HCl; NO_2, dark red vapors, when oxidation of sulphides, etc., takes place in HNO_3.

(2) Solution may take place without effervescence, giving a clear, colorless solution, without a residue. When slow this reaction is sometimes difficult to detect. After boiling with a large amount of the powdered mineral, evaporate a drop of the clear liquid on a watch glass or a piece of Pt foil (or a flake of mica, if HCl or HNO_3 is used). A residue indicates that some of the mineral has gone into solution.

(3) Solution may occur without effervescence and without residue, as in (2), but with a colored solution. Yellowish to brownish red, ferric iron minerals in HCl; green from nickel and from mixtures of copper and iron (the addition of ammonia to the solution gives blue with copper or nickel, very intense with the former); blue from copper, intensified by the addition of an excess of ammonia; pink or pale rose from cobalt minerals.

(4) Solution may occur without effervescence, leaving an insoluble residue. Gelatinous silica from some silicates, appears on evaporation of the acid; powdery or flaky silica separates from some silicates—it is more translucent than the finest powder of most minerals; white opaque metallic oxides, especially from Sn, Sb, and Pb minerals in HNO_3; yellow powder, WO_3, from some tungstates in HCl; yellow floating mass of sulphur, often black with particles of the mineral, from many sulphides in HNO_3.

15. With Cobalt Nitrate. The solution is useful with light-colored infusible minerals. Heat a small amount of the fine powder or minute fragments intensely on charcoal in the oxidizing flame; moisten the mineral with the solution, and again ignite to an intense white heat. Distinct colors may be imparted, as follows:

√ *Blue*, aluminum minerals, zinc silicates.

Bluish-green, tin oxide.

Yellowish-green, zinc and titanium oxides.

Dark green, oxides of antimony and cobalt.

Pink, usually pale, from magnesium minerals.

Calcite and aragonite are readily distinguished by reaction with $Co(NO_3)_2$ solution. Place fine powder of calcite and the mineral to be tested in separate test tubes, fill each about one-half inch deep with the solution, and boil both together by holding the tubes side by side over the Bunsen flame. Aragonite is colored a deep lavender by $CoCO_3$ while calcite remains white. The reaction also takes place with calcite on long continued boiling.

16. Precipitates from Solution. The following reagents are most commonly used. For distinctions between the various precipitates, see the tests for the elements on succeeding pages.

Ammonia precipitates hydroxides of Al, Gl, Bi, chromic Cr, Fe, Pb, Ti, and rare earth metals. (In the presence of phosphoric, arsenic, silicic, and hydrofluoric acids various other substances are also precipitated.)

Ammonium carbonate and *ammonium oxalate* precipitate Ca, Sr, and Ba from solutions made alkaline with ammonia.

Ammonium sulphide precipitates from neutral or alkaline solutions sulphides of Fe, Zn, Mn, Co, Ni, and hydroxides of Al, Cr, and rare earth metals.

Barium chloride precipitates $BaSO_4$ from acid solutions of a sulphate—a delicate test.

Hydrochloric acid precipitates chlorides of Ag, Pb, and mercurous Hg from solutions in HNO_3.

Silver nitrate precipitates silver chloride, bromide, or iodide from solutions of the corresponding minerals in water or HNO_3.

Sodium phosphate precipitates Mg from solutions in which ammonia and ammonium carbonate give no precipitates or in the filtrate after precipitating with these reagents.

Sulphuric acid precipitates sulphates of Pb, Ba, and Sr, and also Ca in concentrated solutions.

REACTIONS FOR THE ELEMENTS

(For list of elements, see page 58; abbreviations, page 60)

ALUMINUM (Al; trivalent; at.wt. 27.1)

(1) **Ign. with Cobalt Nitrate.** Fine powder of light-colored infus. Al minerals assume a fine blue color when moistened with the solution and intensely heated either on ch. or in a small loop of Pt wire. Zn silicates also give blue color, but will also yield test for Zn.

(2) **Precipitation with Ammonia.** Added in slight excess to acid solutions, gelatinous $Al(OH)_3$ is precipitated. To distinguish from other similar-looking precipitates obtained in the same way, filter, wash the ppt., place part of it in test tube with H_2O and KOH; if it is $Al(OH)_3$ it will go easily into solution. Burn the filter (in crucible or on ch.) and the rest of the ppt. will give foregoing test with cobalt nitrate.

For Al in silicates, see Silicon (2).

ANTIMONY (Sb; trivalent and pentavalent; at.wt. 120.2)

(1) **Oxide Subl. on ch.** Heat fragments on ch. in o.f. A dense white subl. of Sb_2O_3 forms very near the assay (compare As). Where thin the coating looks bluish. Subl. is volatile and may be driven about readily by the o.f. or r.f. No distinctive odor (compare As) unless S or As is present.

(2) **Antimonate Subl. in o.t.** When heated in o.t. most Sb sulphides yield a heavy white subl., $SbSbO_4$, along the

under side of the tube, which is non-vol. (compare As), straw-yel. when hot and white on cooling.

(3) **Oxysulphide Subl. in c.t.** On intense ign. sulphides yield a black subl. of Sb_2S_2O, rich redh.-brn. on cooling. Dif. vol.

(4) **Iodide Subl. on Gypsum.** Mixed with "bismuth flux" or moistened with HI and heated in o.f. on gypsum tablet, a red subl. of SbI_3, which disappears in fumes of strong ammonia.

(5) **Flame Color.** Sb volatilizes in r.f. and gives a pale greenish color to the flame. Pt forceps must not be used.

ARSENIC (As; trivalent and pentavalent; at.wt. 75)

(1) **Oxide Subl. on ch.** Metallic As, its sulphides and the arsenides when heated on ch. yield white fumes of a garlic-like odor and a white crystalline subl. of As_2O_3 far from the assay.

(2) **Oxide Subl. in o.t.** Subl. and odor like preceding are produced in the tube. Easily volatile and driven out of the tube.

(3) **Metallic Mirror in c.t.** The metal and some arsenides yield a brilliant black arsenical mirror. When abundant the part nearest the assay crystallizes and looks gray. By breaking off the closed end of tube and heating the subl. the garlic odor is produced. Oxygen compounds require powdered charcoal also in the c.t.

(4) **Iodide Subl. on Gypsum.** Powder mixed with "bismuth flux" or moistened with HI and heated in o.f. on gypsum tablet, a vol. orange-yel. subl. of AsI_3 forms.

(5) **Flame Color.** In r.f. As volatilizes and colors the flame violet.

(6) pptation as NH_4MgAsO_4

BARIUM (Ba; bivalent; at.wt. 137.4)

(1) **Flame Color.** A gnh.-yel. color is imparted to the flame, sometimes intensified by moistening with HCl. Silicates do not give the flame color. Must be distinguished carefully from B and P flame colors.

(2) **Sulphate Precipitate.** A few drops of dilute H_2SO_4. give a white ppt. of $BaSO_4$ from solutions in water and dilute acids. A delicate test and distinguishes from B and P. Insoluble silicates require previous fusion of the finely powdered mineral with 3 volumes of soda in a loop of Pt. wire, which renders them soluble in HCl. Test ppt. for flame color using clean Pt wire. If both Ba and Sr are present a mixed flame results.

(3) **Alkaline Reaction.** Like the other alkaline earths and most alkalis, some Ba minerals give alkaline reaction on moist turmeric paper after ignition.

BISMUTH (Bi; trivalent; at.wt. 208)

(1) **Metallic Bi and Oxide Subl. on ch.** Heat the mineral with 3 times its volume of soda on ch. Brittle metallic globules of Bi are obtained and a yellow coating of Bi_2O_3 which is white further away. Subl. much like that of Pb, but metal less malleable; distinguished by the following test.

(2) **Iodide Ppt. on ch. and Gypsum.** Mix the powdered mineral with "bismuth flux" or moisten with HI and heat in the o.f. on ch. The subl. is yellow near the assay and bordered by brilliant red BiI_3. On a gypsum plate the subl. is chocolate-brown but changes to a brilliant red on exposure to strong ammonia fumes.

Boron (B; trivalent; at.wt. 11)

(1) **Flame Color.** A somewhat yellowish-green (siskin-green) flame color. Must not be confused with Ba flame. Readily distinguished by other tests. Some B minerals require heating with 3 volumes of a mixture of $3KHSO_4$ and $1CaF_2$; the BF_2 formed gives a momentary color to the flame.

(2) **With Turmeric Paper.** Moisten turmeric paper with a dilute HCl sol. of the mineral and dry it on the outside of a test tube containing boiling water. The paper becomes reddish-brown; on moistening with ammonia it becomes black. Insol. minerals must first be fused in fine powder with 3 volumes of soda on a loop of Pt wire and then dissolved in HCl.

Bromine (Br; univalent; at.wt. 79.9)

(1) **Precipitation as Bromide.** Solutions of bromides in water or dilute HNO_3 yield a white ppt. of AgBr when $AgNO_3$ is added.

(2) **Pb Bromide Subl. in c.t.** AgBr heated in c.t. with galena (PbS) yields a subl. of $PbBr_2$, which is S-yellow while hot and white when cold.

Cadmium (Cd; bivalent; at.wt. 112.4)

(1) **Oxide Subl. on ch.** Heated on ch. with 3 volumes of soda, metallic Cd is volatilized and sublimed as reddish-brown CdO, which is yellow distant from the assay and iridescent if only a little forms.

Calcium (Ca; bivalent; at.wt. 40.1)

(1) **Flame Color.** Some Ca minerals give yelh.-red color to the flame (green through green glass), often strengthened by moistening with HCl. Must not be confused with the much redder Sr and Li flames.

(2) **Sulphate ppt.** A few drops of dilute H_2SO_4 added o an HCl sol. of a Ca mineral precipitates white $CaSO_4 \cdot 2H_2O$, which goes into solution on addition of water and boiling. This sol. in water distinguishes it from Sr and Ba.

(3) **Carbonate or Oxalate ppt.** Ammonium carbonate or oxalate added to a solution made strongly alkaline with ammonia forms a white ppt. of the corresponding Ca compound. The oxalate is also formed in slightly acid solutions and this test can be applied in solutions of phosphates, silicates, and borates, which cannot be made alkaline with ammonia without precipitating Ca salts.

(4) **Alkaline Reaction.** Like other alkaline earths and most of the alkalis, some Ca minerals give an alkaline reaction on moist turmeric paper after ignition.

For Ca in silicates, see Silicon (2).

Carbon (C; tetravalent; at.wt. 12)

(1) **Odor in c.t.** The characteristic empyreumatic odor of distilling organic substances is given in c.t. by hydrocarbons and bituminous coal. Anthracite does not yield it, but is combustible in the o.f.

(2) **CO_2 from Carbonates.** Heat fragments of the mineral in the c.t. held horizontally with a drop of $Ba(OH)_2$ in the open end of the tube; the latter is clouded with a white ppt. of $BaCO_3$.

(3) **Effervescence with Acids.** Treat the powdered mineral with dilute HCl, HNO_3, or H_2SO_4, and warm if necessary. Guard against mistaking boiling for effervescence. Tip the test tube gently and pour accumulated CO_2 (gas) into another tube containing $Ba(OH)_2$; on shaking the latter a white ppt. of $BaCO_3$ forms. Concentrated acids do not yield the test unless the salts formed are soluble in the acids.

CHLORINE (Cl; univalent; at.wt. 35.5)

(1) **Flame Color with CuO.** Mix powdered mineral with CuO and moisten with H_2SO_4, dry gently on ch. and ignite. Or saturate a small s.ph. bead with CuO, add a fragment of the mineral and heat in the o.f. In either case the azure-blue flame of $CuCl_2$ will appear. Br gives a similar reaction.

(2) **Evolution of Cl.** A powdered chloride heated in a small test tube with a little pyrolusite (MnO_2) and 4 times its volume of $KHSO_4$ gives off Cl gas, which is recognized by its pungent odor and its bleaching effect on a piece of moist litmus paper placed inside the tube. AgCl and silicates containing Cl require fusion first with 3 volumes of soda.

(3) **AgCl ppt.** From a solution of a chloride in water or dilute HNO_3 a few drops of $AgNO_3$ sol. ppts. white AgCl, curdy if abundant, bluish opalescent if little. Br and I give similar reactions. Light soon changes color of the ppt. to violet. Insoluble minerals must first be fused with 3 volumes of soda.

(4) **Sublimate with Galena.** To distinguish chloride, bromide, and iodide of Ag, heat in c.t. with powdered galena. A subl. of $PbCl_2$ forms colorless globules which are white when cold; $PbBr_2$ is S.-yel. hot and white when cold; PbI_2 is dark orange-red hot and lemon-yellow cold. The presence of Br obscures that of Cl and I obscures both of the others.

CHROMIUM (Cr; trivalent and sexivalent; at. wt. 52)

(1) **Borax Bead Reac.** In o.f. yellow hot (red with much), yel.-grn. cold. In r.f. green hot and cold.

(2) **S.ph. Bead Reac.** In o.f. dirty green hot, clear green cold. In r.f. similar colors but weaker. V differs in giving yellow color to s.ph. bead in o.f.

(3) **Soda Bead Reac.** In o.f. dark yellow while hot, light yellow and opaque cold; in r.f. yelh.-green opaque when cold.

Cobalt (Co; bivalent; at.wt. 59)

(1) **In Borax and s.ph. Beads.** Fine blue in both o.f. and r.f. When Cu or Ni interferes remove the bead from the Pt wire and fuse it on ch. with a granule of Sn and the Co color will appear.

Columbium (Niobium) (Cb; pentavalent; at.wt. 93.5)

(1) **Reduction in Solution.** Mix powdered mineral with 5 volumes of borax, moisten to a paste with water and fuse in a double loop of Pt wire (Fig. 9*b*). Crush 2 or 3 such beads to powder and boil with HCl to a clear solution. Add Sn and boil and the sol. becomes blue, which changes slowly to brown on continued boiling and disappears on dilution. With Zn instead of Sn the blue color changes quickly to brown. W gives similar tests, but other tests for that element will distinguish.

Copper (Cu; bivalent and univalent; at.wt. 63.6)

(1) **Flame Color.** The oxide and oxidized sulphides give an emerald-green color. When moistened with HCl the flame is azure-blue. The same result is obtained by adding a grain of common salt, NaCl, to a s.ph. bead saturated with the substance.

(2) **Metallic Cu on ch.** Oxides, and sulphides that have been previously roasted, yield globules of red malleable Cu when fused on ch. with 3 volumes of a flux of equal parts of soda and borax in r.f.

(3) **Borax and s.ph. Bead Reactions.** In o.f. green hot and blue cold; in r.f. pale with little Cu, red and opaque with much.

A *ruby red transparent bead* is obtained by adding a little tin or tin-bearing substance to a borax bead made pale blue with Cu in o.f. Dissolve thoroughly in o.f. and reduce slightly. If too much reduced the bead is colorless. A delicate test for either Cu or Sn.

(4) **Color in Solution.** Blue or green sol. in HNO_3 or HCl, made deep blue by adding ammonia in excess. Ni gives a much fainter blue by similar treatment.

(5) **Cuprous Cu.** Dissolve mineral in a little HCl and add water. A white ppt. of cuprous chloride (CuCl) appears.

FLUORINE (F; univalent; at.wt. 19)

(1) **HF in c.t.** Mix the finely powdered mineral with an equal volume of powdered glass and 3 volumes of $KHSO_4$ and heat gently in c.t. The HF liberated attacks the glass and forms SiF_4, which decomposes to H_2SiF_6 with separation of SiO_2; this forms a volatile white subl. in the tube. Break off bottom of tube, wash subl. with water and dry; the remaining subl., SiO_2, is non-vol.

(2) **Etching Glass.** Mix powdered mineral with a few drops of conc. H_2SO_4 and spread over a glass that has been previously coated with paraffin and scratched with a pointed instrument. Let stand 5 minutes or longer. Wash off the acid, warm the glass, and wipe off paraffin to observe etching.

(3) **With $NaPO_3$ in c.t.** Mix the powdered mineral with 5 times the volume of powdered s.ph. beads and heat very hot in c.t. A subl. forms as in (1) and may be tested as there described.

GOLD (Au; univalent and trivalent; at.wt. 197.2)

(1) **Metal with Soda on ch.** The color, fusibility, malleability, and insolubility in any single acid serve to distinguish it from other metals when present in visible particles.

(2) **Purple of Cassius.** Carefully evaporate the solution in aqua regia to dryness, add a little water and dilute solution of stannous chloride ($SnCl_2$). The purple ppt. of colloidal Au and $Sn(OH)_2$ are soluble in ammonia to a reddish liquid.

Hydrogen (H; univalent; at.wt. 1)

(1) **Water in c.t.** Minerals containing hydroxyl, acid hydrogen, or water of crystallization, when heated in c.t. give off water which condenses in the cold part of the tube. Hydroxyl and acid H require high temperature. Some salts of weak bases yield acid water and from some ammonia compounds it is alkaline, as shown by a strip of red litmus paper inserted in the tube.

Iodine (I; univalent; at.wt. 126.9)

(1) **Iodide Subl. with Galena.** Heat the powdered mineral with powdered galena in c.t.; a subl. of PbI_2 is formed which is dark orange-red while hot and lemon-yellow when cold.

(2) **Ppt. with $AgNO_3$.** From dil. HNO_3 solution $AgNO_3$ ppts. white AgI, which differs from AgCl and AgBr in being nearly insoluble in ammonia.

(3) **I with $KHSO_4$.** Violet I vapor is formed when iodides are heated in c.t. with $KHSO_4$.

Iridium (Ir; trivalent and tetravalent; at.wt. 193.1)

One of the rare Pt metals. See Platinum.

Iron (Fe; bivalent and trivalent; at.wt. 55.8)

(1) **Magnetism.** A few Fe minerals are magnetic and many become so on heating in r.f. (or roasting and then heating in r.f. in case of sulphides and arsenides). The test is

more delicate if the powder is fused with a little soda, giving a magnetic slag. In all cases only the cold material is magnetic.

(2) **Borax Bead Reac.** With small amount of mineral the bead in o.f. is yellow hot and nearly colorless cold; with much it is bnh.-red hot and yellow cold. With little in r.f. it becomes pale green hot and colorless cold; with much it is bottle-green hot and paler when cold. With sulphides and arsenides the bead test can be made only after roasting.

(3) **Hydroxide ppt.** When ammonia is added to a dil. HNO_3 sol. or to HCl sol. which has been boiled with a few drops of HNO_3, a bnh.-red ppt. of $Fe(OH)_3$ is formed. In ferrous HCl sol. ammonia gives a dirty green $Fe(OH)_2$ ppt. which slowly turns brown by oxidation.

(4) **Ferrous and Ferric Fe.** In cold dilute acid solutions potassium ferricyanide, $K_6Fe_2(CN)_{12}$, gives a dark blue ppt. with ferrous Fe; in ferric solutions it deepens the color but gives no ppt. Potassium ferrocyanide, $K_4Fe(CN)_4$, gives a dark blue ppt. with ferric solutions; from ferrous sol. it gives a pale bluish-white ppt. which rapidly becomes blue. NH_4CNS or KCNS gives a dark red color to ferric solutions.

Minerals insol. in acids must first be fused in c.t. with 3 volumes of borax glass (powdered borax beads). Break off lower end of tube and boil in a little HCl for a minute; dilute the sol., divide it into two parts, and test as above for ferrous and ferric Fe.

For Fe in silicates, see Silicon (2).

LEAD (Pb; bivalent and tetravalent; at.wt. 207.1)

(1) **Metal and Subl. on ch.** Mix 1 part powdered mineral, 1 part powdered charcoal, and 3 parts soda, moisten and fuse in r.f. on ch. Globules of soft, malleable, and sectile metal form, bright in r.f. and dull on cooling; also subl. of PbO, yellow near assay, bluish-white further away.

(2) **Iodide Subl. on ch.** Heat powdered mineral with 3 volumes of "bismuth flux" in o.f. on ch. A chrome-yel. subl. of PbI_2 forms near and greenish-yellow far from assay.

(3) **Ppts. from Solution.** From solution in dil. HNO_3 either H_2SO_4 or HCl forms a white ppt. ($PbSO_4$ or $PbCl_2$). From a boiling solution of the mineral in HCl white $PbCl_2$ crystallizes out on cooling.

LITHIUM (Li; univalent; at.wt. 6.9)

(1) **Flame Color.** Crimson flame when heated in Pt forceps or from powdered mineral on clean Pt wire (invisible through green glass). For silicates better results are obtained by mixing the mineral with equal parts of powdered gypsum. Flame color is much like that of Sr, but redder than that of Ca. Compare Sr and Ca.

MAGNESIUM (Mg; bivalent; at.wt. 24.3)

(1) **Color with Cobalt Nitrate.** Some light-colored Mg minerals become pale pink when strongly ignited after moistening with $Co(NO_3)_2$ sol.

(2) **Alkaline Reac.** Some Mg minerals give alkaline reac. on moist turmeric paper after ignition, like the alkalis and alkaline earths, but weaker, and less decisive.

(3) **Ppt from Solution.** If HCl sol., boil with a drop of nitric acid, make strongly alkaline with ammonia, and remove Fe, Al, and Ca by successive precipitation with ammonia and ammonium oxalate, filtering each time a precipitate appears. To the clear filtrate add sodium phosphate and a crystalline ppt. of $NH_4MgPO_4 \cdot 6H_2O$ appears.

For Mg in silicates, see Silicon (2).

MANGANESE (Mn; bivalent, trivalent, tetravalent; at.wt. 54.9)

Minerals containing S, As, etc., must be roasted in o.f. before making bead tests.

(1) **Soda Bead Reac.** In o.f. green while hot, bluish-green cold; in r.f. white.

(2) **Borax Bead Reac.** In o.f. opaque while hot, reddish-violet when cold, black if too much is used. In r.f. colorless. Similar results in s.ph. but not so delicate.

(3) **Evolution of Cl.** Higher oxides of Mn decompose HCl with evolution of Cl gas.

MERCURY (Hg; univalent and bivalent; at.wt. 200)

(1) **Metal in c.t.** Mix the powdered mineral with 4 volumes of soda that has been dried by heating nearly to redness on clean metal or in a procelain crucible; put mixture in c.t., cover with dry soda, and heat gradually. Hg appears as gray subl. or as globules on the walls of the tube. Alone in c.t. most Hg compounds volatilize without decomposing. Cinnabar gives a black subl. like the As mirror.

(2) **Hg Ppt. on Cu.** Clean Cu in a Hg sol. receives a coating of metallic Hg, giving the appearance of silver plating.

MOLYBDENUM (Mo; tetravalent and sexivalent; at.wt. 96)

(1) **Subl. in o.t.** Thin flakes of molybdenite at a high temperature in o.t. give a yellow subl. of MoO_3, frequently also delicate crystals.

(2) **Flame Color.** At tip of blue flame gives a pale yelh.-green color.

(3) **S.ph. Bead Reac.** With a small amount of the oxide in o.f. the bead is yelh.-green while hot, nearly colorless cold; in r.f. dirty green hot, fine green on cooling.

Treatment with conc HCl
forming a thiocyanate.

(4) **Color in Sol.** Place finely powdered mineral with a minute scrap of paper (about 1 mm. square) in a test tube with a few drops of water and an equal quantity of conc. H_2SO_4; heat till copious acid fumes form, let cool, and add water, one drop at a time. A deep blue color appears and quickly disappears with much dilution.

NICKEL (Ni; bivalent; at.wt. 58.7)

(1) **Borax Bead Reac.** In o.f. violet while hot, redh.-brown cold; opaque by long heating in r.f. On ch. with Sn the bead becomes colorless. Co in small amt. obscures the bead test for Ni.

(2) **Color of Sol. and Ppt.** Sol. in HNO_3 is apple-green; becomes blue with ammonia. Compare the much deeper blue with Cu from this treatment.

(3) **Dimethylglyoxime Test.** To a solution of the mineral add ammonia in slight excess and a few drops of the reagent. A scarlet crystalline ppt. forms. If very little Ni is present, boil, and red needles form on cooling. A very delicate test.

NITROGEN (N; trivalent and pentavalent; at.wt. 14)

(1) **Deflagration on ch.** Nitrates deflagrate (flash somewhat like gunpowder) upon ignition on ch.

(2) **Fumes in c.t.** Heat mineral powder in c.t. with $KHSO_4$. NO_2 fumes given off are recognized by red color on looking into the end of the tube.

OSMIUM (Os; bivalent, tetravalent, etc.; at.wt. 190.9)

One of the rare platinum metals. See Platinum.

OXYGEN (O; bivalent; at.wt. 16)

(1) **O gas in c.t.** Some higher oxides give off O when heated in c.t. A glowing stick inserted will burn brightly.

(2) **Cl Gas with HCl.** Some higher oxides decompose HCl with the liberation of free Cl, which has a pungent odor and bleaches moist litmus paper inserted in the tube.

PALLADIUM (Pd; bivalent and tetravalent; at.wt. 106.7)

One of the rare platinum metals. See Platinum.

PHOSPHORUS (P; pentavalent; at.wt. 31)

(1) **Ppt. with Ammonium Molybdate.** Dissolve the powdered mineral in HNO_3, previously fusing in soda bead if insol. Add a few drops of the sol. to a test tube containing ammonium molybdate and let stand a few minutes; a yellow ppt. forms.

(2) **Flame Color.** Pale bluish-green; moistening with H_2SO_4, is required with some minerals.

PLATINUM (Pt; bivalent and tetravalent, at.wt. 195.2)

(1) **Platinum** is recognized by its grayish-white color, infusibility, insolubility in any single acid, and reddish-yellow solution in aqua regia. It usually contains iron and traces of the other metals of the Platinum Group, of which the following are the most important:

(2) **Osmium** gives the very penetrating and disagreeable odor of OsO_4 when the fine powder is heated in c.t. with $NaNO_3$ or KNO_3.

(3) **Iridium** and **Iridosmine** are hard ($H = 6–7$), insoluble even in aqua regia. Fusion with $NaNO_3$ in c.t. oxidizes some Ir; break off the lower end of the tube and boil the mass in aqua regia. The solution becomes deep red to reddish-black.

Test [illegible]

(4) **Palladium** has a bluish tarnish, which is removed and a Pt-like color restored in r.f. The tarnish is renewed by moderate heat in o.f.

POTASSIUM (K; univalent; at.wt. 39.1)

(1) **Flame Color.** Pale violet, obscured by Na; violet or purplish-red through blue glass, which eliminates the yellow of Na. For silicates mix with an equal volume of powdered gypsum and heat on a Pt wire the end of which has been moistened to make the powder adhere.

(2) **Alkaline Reaction.** Some K minerals, like those containing some other alkalis and the alkaline earths, give an alkaline reac. on moist turmeric paper after intense ignition.

For K in silicates, see Silicon (2).

SELENIUM (Se; bivalent and sexivalent; at.wt. 79.2)

(1) **Odor and Subl. on ch.** Radish-like odor. If abundant, brownish fumes form and a silvery SeO_2 coating, which may have a border of red from admixture of Se.

(2) **Flame Color.** The subl. obtained in (1) is volatile in r.f. and imparts a fine azure-blue color to the flame.

(3) **Subl. in o.t.** White crystalline SeO_2 subl. reddened by admixture of Se; volatile and give a beautiful blue color to flame if the end of the tube is held so that the fumes enter the reducing part of the Bunsen flame.

(4) **Subl. in c.t.** Fused black globules of Se, the smallest deep red to brown by transmitted light. Some white SeO_2 may form above the Se.

SILICON (Si; tetravalent; at.wt. 28.3)

(1) **Gelatinization.** Silicates that are completely soluble in acids give on continued boiling and evaporation a jelly of H_2SiO_3. HNO_3 is best, but HCl will serve in most cases.

(2) **Insol. Residue in Acids.** Insol. silica in powdery form remains after solution of the bases of some minerals. In suspension it makes the solution translucent and not so white and milky as the powder of an insol. mineral. Verify solution by evaporating a drop of the clear liquid on Pt foil or a watch glass (or a flake of mica if HCl or HNO_3 is used) and note considerable residue if solution has occurred.

Evaporate the solution obtained in (1) or (2) to dryness, moisten with conc. acid, and heat to boiling, then add 2 parts water and boil again. The bases go into sol. but the silica remains and is removed by filtering. For insol. silicates first fuse in beads on Pt wire with 3 parts of soda, dissolve in dil. HNO_3, evaporate to dryness, and proceed as before. It is convenient to use a double loop (Fig. 9*b*) and prepare 2 or 3 large beads, in order to provide a sufficient quantity for distinct reactions. This is especially important in the following tests.

Detection of Bases in Silicates. (*a*) To the filtrate from the preceding operations if not a nitric acid solution, add a little HNO_3, heat to boiling and add ammonia in slight excess. Al and Fe are precipitated as hydroxides ($Al(OH)_3$ and $Fe(OH)_3$). If the ppt. is light-colored there is little or no Fe; if it is reddish-brown there is considerable Fe and further test must be made for Al as follows: (*b*) Filter; place the ppt. in a test tube with a little water and a small fragment of stick potash (KOH) and boil. $Al(OH)_3$ goes into solution and is separated from insoluble $Fe(OH)_3$ by filtering. Make the filtrate acid with HCl, boil, and add ammonia in excess to precipitate $Al(OH)_3$ again.

(*c*) Heat filtrate from (*a*) to boiling and add a little ammonium oxalate to precipitate Ca. Let stand 10 minutes and filter. If filtrate is turbid, pass it repeatedly through the same filter till it comes through clear.

(*d*) Add to the filtrate from (*c*) a little more ammonium oxalate to make sure that all Ca has been removed. If no ppt. forms add sodium phosphate and strong ammonia to precipitate Mg. It may have to stand for some time after cooling before the precipitate forms.

(*e*) If alkalis are to be tested for, filter off the Mg ppt. of (*d*), evaporate the filtrate to dryness and heat to redness to drive off ammonia salts. Test the residue for K and Na flame colors with a Pt wire.

(3) **In s.ph. Bead.** An insol. skeleton of translucent silica remains when the powdered mineral is fused in s.ph. bead.

SILVER (Ag; univalent; at.wt. 107.9)

(1) **Metal on ch.** Fuse powdered mineral with 3 volumes of soda on ch.; a malleable metal globule is obtained which is bright both in the flame and after cooling. Test according to (2) below. Compounds with S, As, and Sb on roasting in o.f. on ch. yield Ag globule which is brittle with Sb.

(2) **Subl. on ch.** When Pb and Sb are present or have been added, the subl. of PbO and Sb_2O_3 on ch. is colored reddish to deep lilac by Ag.

(3) **AgCl Ppt.** Dissolve the mineral in conc. HNO_3 and dilute the sol.; add a few drops of HCl or a little common salt and a white ppt. of AgCl forms. Darkens on exposure to light and is sol. in ammonia. Collect ppt. on filter paper and test according to (1) above.

SODIUM (Na; univalent; at.wt. 23)

(1) **Flame Color.** Deep yellow, invisible through dark blue glass. For non-vol. silicates mix powdered mineral with equal volume of powdered gypsum and heat on the point of a Pt wire which has been previously moistened so that powder will adhere.

(2) **Alkaline Reac.** Some Na minerals, like those containing most other alkalis and the alkaline earths, give alkaline reac. on moist turmeric paper after ignition.

For Na in silicates, see Silicon (2).

STRONTIUM (Sr; bivalent; at.wt. 87.6)

(1) **Flame Color.** Crimson, from fragment in forceps or from powder on Pt wire moistened with HCl (faint yellow

through green glass). Much like the Li flame; redder than the Ca flame and more persistent.

(2) **Alkaline Reac.** Like many minerals containing alkalis and other alkaline earths, some Sr minerals give alkaline reac. on moist turmeric paper after ignition. No Li minerals give this reaction.

(3) **Sulphate ppt.** A sol. of a Sr mineral gives a white ppt. of $SrSO_4$ on addition of a few drops of dil. H_2SO_4 (dif. from Li) if sol. is not very dilute or too much acid. Ppt. does not dissolve on addition of water and boiling, as does $CaSO_4$. This test is useful for silicates and phosphates, which do not yield tests (1) and (2).

SULPHUR (S; bivalent and sexivalent; at.wt. 32.1)

Sulphides:

(1) **Fumes in o.t. and on ch.** Finely powdered sulphides in o.t. give sharp pungent SO_2 fumes, which give acid reac. on moist litmus paper in upper end of tube. With Fe and Cu some white fumes of SO_3 appear and H_2SO_4 condenses in the tube. Similar results on ch. in o.f., but less delicate. Some sulphides give blue flame from burning S on ch.

(2) **Subl. in c.t.** Some sulphides yield in c.t. a subl. of S, which is a reddish liquid while hot and a yellow solid when cold.

(3) **Reac. with Soda.** Fuse powdered mineral b.b. on Pt foil, ch., or a flake of mica, with 3 volumes of soda, place the mass on clean Ag and moisten with water; a black stain of Ag_2S forms. The fused mass moistened with HCl yields H_2S, as in (5) below. This test is not reliable in the presence of Se and Te. Also the gas or ch. may give a slight reac. for S.

(4) **Sol. in HNO_3.** In hot conc. HNO_3 sulphides are oxidized with the formation of H_2SO_4 and red NO_2 fumes. Dilute part of the sol. and add $BaCl_2$; a white ppt. of $BaSO_4$

forms. Free S may also float on the solution, either yellow or black with particles of the mineral.

(5) **H_2S with HCl.** Some sulphides dissolve in HCl with the evolution of H_2S gas, which is recognized by its offensive odor.

Sulphates:

(1) **$BaSO_4$ ppt.** $BaCl_2$ added to a dil. HCl sol. of a sulphate gives a white ppt. of $BaSO_4$, which does not dissolve on addition of water and boiling, as does $CaSO_4$.

(2) **Reac. with Soda.** Fuse the powdered mineral with equal volume of powdered ch. and 2 volumes of soda on ch., Pt foil, or a flake of mica till effervescence ceases; then test on Ag or with HCl as in (3) for sulphides.

TELLURIUM (Te; bivalent; at.wt. 127.5)

(1) **Subl. on ch.** Heated in o.f. on ch. a white subl. of TeO_2 forms near assay, resembling Sb_2O_3. Subl. is vol. in r.f. and gives a pale greenish color to the flame.

(2) **Subl. in o.t.** Similar to results on ch.; subl. volatilizes very slowly and fuses into globules which are yellow while hot and white or colorless when cold.

(3) **Subl. in c.t.** Metallic globules of Te and white subl. of TeO_2, as in (2), form in c.t.

TIN (Sn; tetravalent; at.wt. 119)

(1) **Reduction by H.** With dil. HCl and fragments of Zn cassiterite develops a dull gray coating of metallic Sn, which becomes bright and gives the characteristic odor of Sn on flesh when rubbed between the fingers.

(2) **Metal and Subl. on ch.** The powdered mineral fused on ch. in r.f. with equal volume of powdered ch. and 2 volumes of soda gives globules of white malleable Sn, which are bright

in r.f. and become dull in the air. Long-continued ignition gives a white subl. of SnO_2 on ch. In somewhat conc. warm HNO_3 the metal does not dissolve but forms white H_2SnO_3. Distinguished from Pb and Bi by accompanying subl. on ch. and from Ag by subl. and dull surface of globule in air.

For a delicate borax bead test, see Copper (3).

Titanium (Ti; trivalent and tetravalent; at.wt. 48.1)

(1) **Color of Sol.** After fusion with borax or soda and solution in HCl, the sol. assumes a delicate violet color on boiling with Sn.

(2) **S.ph. Bead Reac.** In o.f. yellow while hot, colorless cold; in r.f. yellow hot, delicate violet cold. Best reduced with a granule of Sn on ch. When other coloring elements are present use test (1), above.

(3) **Test with H_2O_2.** Fuse the mineral with soda, boil in a small amount of conc. H_2SO_4 and an equal volume of water till clear. Dilute and add H_2O_2; the sol. becomes redh.-yellow to amber, according to the quantity of Ti.

Tungsten (W; sexivalent; at.wt. 184)

(1) **S.ph. Bead Reac.** In o.f. colorless; in r.f. green hot, fine blue cold.

(2) **Residue in HCl.** When decomposed by HCl a yellow residue of WO_3 is obtained. Add Sn and continue boiling; a blue color is obtained, which finally changes to brown.

(3) **Reduction on Al.** To a drop of water on Al add the finely powdered mineral and a small drop of HCl. A blue color develops on standing.

(4) **Fusion with Soda.** If insol. in HCl, fuse powder on Pt wire with 6 volumes of soda, pulverize and dissolve in water, filter, acidify with HCl, and boil with Sn. The blue sol. is obtained as in (2).

URANIUM (U; tetravalent and sexivalent; at.wt. 238.5)

(1) **S.ph. Bead Reac.** In o.f. yellow while hot, yelh.-green cold; in r.f. a fine green.

Ppt. [illegible] as [illegible] NH_4 uranate ($(NH_4)_2U_2O_7$)

VANADIUM (V; pentavalent; at.wt. 51)

(1) **S.ph.Bead Reac.** In o.f. yellow to deep amber, fading a little on cooling; in r.f. dirty greenish while hot, fine green cold.

(2) **Color of Sol.** To an acid sol. add a few drops of H_2O_2. The sol. becomes reddish-brown from pervanadic acid, HVO_4. A very delicate test.

ZINC (Zn; bivalent; at.wt. 65.4)

(1) **Subl. on Ch.** Fuse powdered mineral on ch. with ½ its volume of soda and the same amount of powdered ch. ZnO subl. near the assay is pale yellow hot, white cold. Where ch. is previously moistened with $Co(NO_3)_2$ sol. the subl. is green.

(2) **Flame Color.** A large fragment heated near the tip of the blue flame colors it in streaks a vivid pale bluish-green.

(3) **Change of Color.** Many Zn minerals are straw-yellow or canary-yellow while hot and white when cold.

ZIRCONIUM (Zr; tetravalent; at.wt. 90.6)

(1) **Turmeric Paper Test.** Fuse the powdered mineral with soda in a loop of Pt wire and dissolve the bead in a small amount of HCl. Turmeric paper placed in the solution assumes an orange color, which is detected by comparing with a piece of turmeric paper in another tube containing only acid.

CRYSTALLIZATION

There are six systems of crystallization to which all crystals may be assigned. These are distinguished by degrees of symmetry, which is usually expressed in terms of lengths and inclinations of certain lines assumed in the crystal and called crystallographic axes.

(1) **Isometric System.** Three equal axes at right angles to each other. The simple forms and some of the combinations are shown in Figs. 11 to 30.

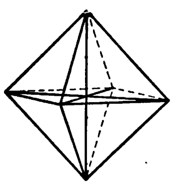

FIG. 11.

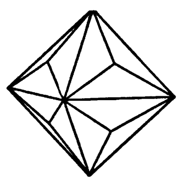

FIG. 12.

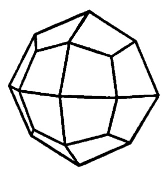

FIG. 13.

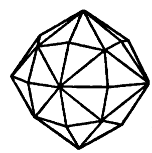

FIG. 14.

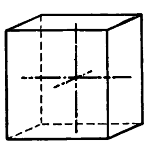

FIG. 15.

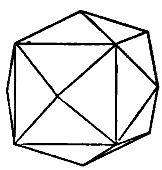

FIG. 16.

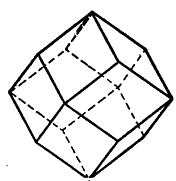

FIG. 17.

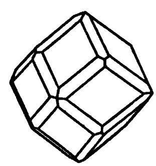

FIG. 18.

ISOMETRIC CRYSTALS: Fig. 11, Octahedron (111); 12, Trisoctahedron (221); 13, Trapezohedron (211); 14, Hexoctahedron (321); 15, Cube, or hexahedron (100); 16, Tetrahexahedron (210); 17, Dodecahedron (110); 18, Combination of dodecahedron and trapezohedron.

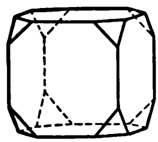

Fig. 19.

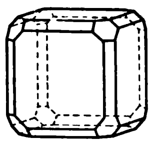

Fig. 20.

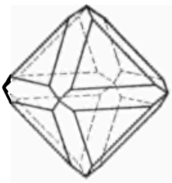

Fig. 21.

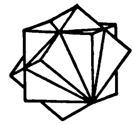

Fig. 22.

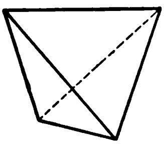

Fig. 23.

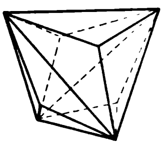

Fig. 24.

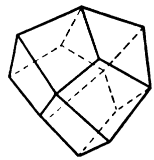

Fig. 25.

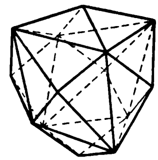

Fig. 26.

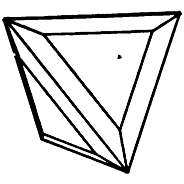

Fig. 27.

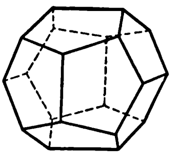

Fig. 28.

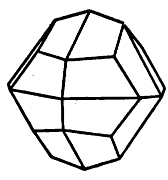

Fig. 29.

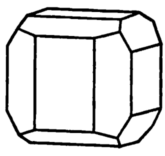

Fig. 30.

Isometric Crystals: Fig. 19, Combination of cube and octahedron; 20, Combinaton of cube, octahedron, and dodecahedron; 21, Combination of octahedron and dodecahedron; 22, Twinned cubes (a *penetration twin*); 23, Tetrahedron (111); 24, Tristetrahedron (211); 25, Deltohedron (221); 26, Hextetrahedron (321); 27, Combination of tetrahedron and tristetrahedron (tetrahedrite); 28, Pyritohedron (210); 29, Diploid (321); 30, Combination of cube and pyritohedron (pyrite).

(2) **Tetragonal System.** Three axes at right angles to each other; two are equal and the third is shorter or longer (Figs. 31 to 39).

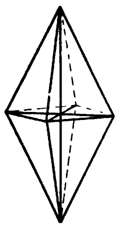

FIG. 31.

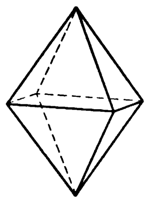

FIG. 32.

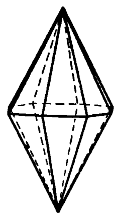

FIG. 33.

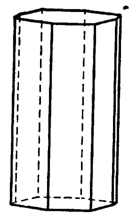

FIG. 34.

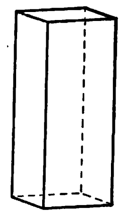

FIG. 35.

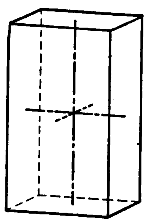

FIG. 36.

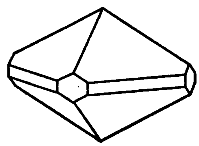

FIG. 37.

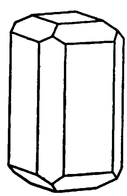

FIG. 38.

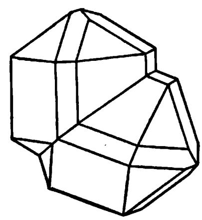

FIG. 39.

TETRAGONAL CRYSTALS: Fig. 31, Pyramid of the first order (111); 32, Pyramid of the second order (101); 33, Ditetragonal pyramid (212); 34, Ditetragonal prism (210); 35, Prism of the first order (110); 36, Prism of the second order (100); 37, Combination of first order prism and pyramid with second order prism (vesuvianite); 38, Combination of basal pinacoid with the same forms as Fig. 37 (vesuvianite); 39, Twin crystal of cassiterite (a *contact twin*).

(3) **Hexagonal System.** Three equal axes at 60° to each other in a horizontal plane; a fourth axis at right angles to these, vertical, is either shorter or longer (Figs. 40 to 51).

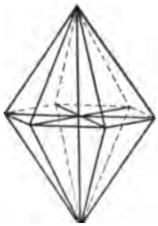
FIG. 40.

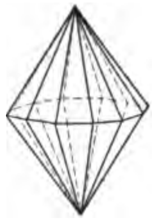
FIG. 41.

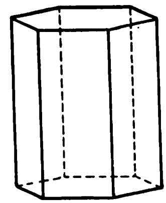
FIG. 42.

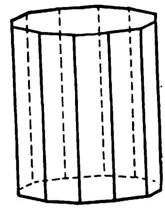
FIG. 43.

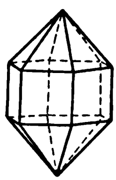
FIG. 44.

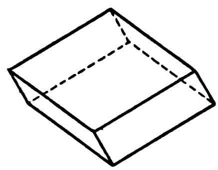
FIG. 45.

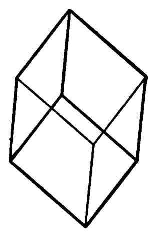
FIG. 46.

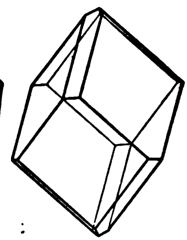
FIG. 47.

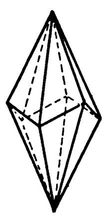
FIG. 48.

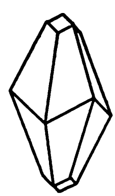
FIG. 49.

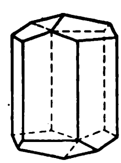
FIG. 50.

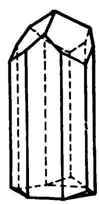
FIG. 51.

HEXAGONAL CRYSTALS: Fig. 40, Pyramid ($10\bar{1}1$); 41, Dihexagonal pyramid ($21\bar{3}1$); 42, Prism ($10\bar{1}0$); 43, Dihexagonal prism ($21\bar{3}0$); 44, Combination of prism and pyramid; 45, Rhombohedron ($10\bar{1}1$) (calcite), 46, Rhombohedron ($02\bar{2}1$) (calcite); 47, Combination of the two preceding rhombohedrons (calcite); 48, Scalenohedron ($21\bar{3}1$) (calcite); 49, Combination of scalenohedron and rhombohedron (calcite); 50, Combination of rhombohedron ($01\bar{1}2$) and prism (calcite); 51, Hemimorphic crystal (tourmaline).

(4) **Orthorhombic System.** Three unequal axes at right angles to each other (Figs. 52 to 59).

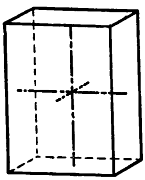

Fig. 52.

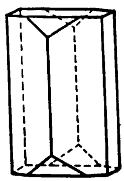

Fig. 53.

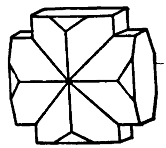

Fig. 54.

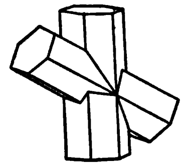

Fig. 55.

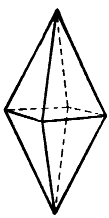

Fig. 56.

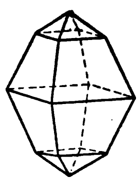

Fig. 57.

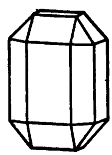

Fig. 58.

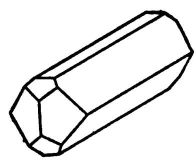

Fig. 59.

Orthorhombic Crystals: Fig. 52, Combination of pinaciods (100), (010), and (001); 53, Combination of basal and brachy pinacoids with prism (110) and macro dome (101) (staurolite); 54, 55, Penetration twins (staurolite); 56, Pyramid (111) (sulphur); 57, Combination of pyramids (111) and (113) (sulphur); 58, Combination of prism, pyramid, domes, and pinacoids (chrysolite); 59, Combination of prism, domes, and basal pinacoid (celestite).

(5) **Monoclinic System.** Three unequal axes, two of which are inclined to each other and are at right angles to the third (Figs. 60 to 66).

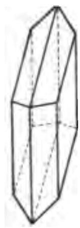

FIG. 60.

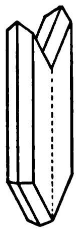

FIG. 61.

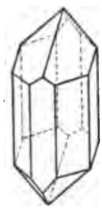

FIG. 62.

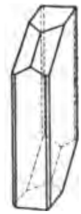

FIG. 63.

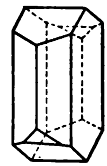

FIG. 64.

MONOCLINIC CRYSTALS: Fig. 60, Hemipyramid (111), prism (110), and clino pinacoid (010), in combination (gypsum); 61, Contact twin (gypsum); 62, Combination of hemipyramids (111) $(\bar{2}21)$, prism (110), and pinacoids (100), (010) (pyroxene); 63, Combination of same forms with basal pinacoid (001) (pyroxene); 64, Combination of prism (110), pinacoids (010) (001), and hemi-ortho domes $(\bar{1}01)$ $(\bar{2}01)$ (orthoclase); 65, Penetration twin (orthoclase); 66, Prism (110), pinacoids (010) (001), and hemi-ortho dome $(\bar{2}01)$ (orthoclase).

(6) **Triclinic System.** Three unequal axes, all inclined to each other (Figs. 67, 68).

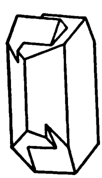

FIG. 65.

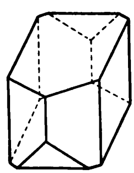

FIG. 66.

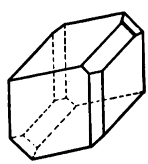

FIG. 67.

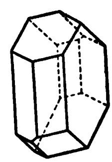

FIG. 68.

TRICLINIC CRYSTALS: Fig. 67, Combination of tetra-pyramids (111) (111), hemi-prisms, (110) $(1\bar{1}0)$, macro pinacoid (100), and macro dome (201) (axinite); 68, Combination of brachy pinacoid (010), basal pinacoid (001), hemi-prisms (110) $(1\bar{1}0)$, and tetra-pyramids $(11\bar{1})$ $(1\bar{1}\bar{1})$ (albite).

DESCRIPTIVE AND TECHNICAL TERMS

The following terms are commonly used in describing the characters of minerals.

Acicular. In slender needle-like crystals.

Adamantine. See Luster.

Amorphous. Non-crystalline structure, like opal or glass.

Amygdaloidal. Forming spherical or almond-shaped masses filling steam or gas cavities in lava.

Anhydrous. Not yielding water in the closed tube. See Hydrous.

Arborescent. Branching like a tree; dendritic.

Bladed. Flattened and elongated, like a knife blade.

Botryoidal. With a surface consisting of small rounded prominences, somewhat like a bunch of grapes pressed closely together.

Brittle. Breaks to powder when cut or hammered.

Capillary. In hair-like or thread-like cyrstals.

Cleavage. The capacity for being split with smooth planes in certain fixed directions, generally parallel to common crystal faces. Cleavage is perfect when the mineral splits very easily. Directions are expressed by the names of the crystal forms; as cubic, parallel to the faces of a cube; octahedral, parallel to the faces of an octahedron, etc. Compare Parting.

Columnar. Parallel grouping of prisms or columns.

Compact. Being a firm aggregate of exceedingly minute particles, like clay.

Conchoidal. See Fracture.

Crystalline. Having regular structure, which, in the absence of crystals, is often shown by cleavage.

Dendritic. Branching like a tree or like fern leaves; arborescent.

Drusy. Covered with minute crystals, giving a rough surface with many glittering faces.

Dull. Without luster or shine of any kind.

Earthy. Clay-like, dull, and composed of minute particles.

Elastic. Springing back when bent, as in plates of mica.

Fibrous. Composed of minute threads, usually with a satiny luster, like asbestos.

Flexible. May be bent without breaking.

Foliated. Separating readily into thin plates; lamellar.

Fracture. The manner of breaking that does not produce smooth planes of cleavage or parting; designated as *conchoidal* when rounded or curved surfaces are produced; *uneven* when rough and irregular; *hackly*, sharp, jagged surfaces, like broken metals; *splintery* when elongated splinters or needles are produced.

Fusibility. Capacity for being fused or melted in the blowpipe flame.

Globular. Having a surface composed of rounded prominences, somewhat larger and more prominent than botryoidal.

Glowing. Emission of a bright light when intensely heated; a property of infusible substances, particularly oxides of Ca, Mg, Zr, and Th.

Granular. Consisting of crystalline grains or particles of about uniform size.

Greasy. See Luster.

Hackly. See Fracture.

Hardness. Resistance to being scratched, commonly indicated by numbers according to the following 10 minerals, called the *Scale of Hardness:* 1. Talc; 2. Gypsum; 3. Calcite; 4. Fluorite; 5. Apatite; 6. Orthoclase; 7. Quartz; 8. Topaz; 9. Corundum; 10. Diamond. With a little practice the degree of hardness can be determined very closely by the use of the

finger nail (a little above 2), a knife blade (a little above 5), and a piece of quartz (7), by noting the ease or difficulty with which a mineral is scratched by one of these.

Hemimorphic. Having crystals with the opposite ends differently terminated.

Hydrous. Yielding water when heated in the closed tube; from water of crystallization, hydroxyl, or acid hydrogen.

Iridescent. Having colors like a soap bubble; often due to a thin coating or a slight surface alteration.

Isomorphic. Elements or compounds capable of replacing each other in all proportions or of crystallizing together to form homogeneous mixed crystals are called isomorphic. Thus calcite, $CaCO_3$, may contain varying amounts of $MgCO_3$, $FeCO_3$, and $MnCO_3$; Fe, Zn, Pb, and Ag may replace part of the Cu in tetrahedrite (gray copper ore); etc.

Lamellar. See Foliated.

Luster. The appearance of a mineral due to its manner of reflecting and refracting light; designated as *metallic,* the luster of a metal; *submetallic, metalloidal,* somewhat like a metal. Metallic and submetallic minerals are opaque and give very dark-colored powder or streak. Non-metallic lusters include *vitreous,* like glass; *adamantine,* brilliant, like diamond; *resinous,* the appearance of resin; *greasy* or *oily,* as if slightly oiled; *pearly,* like mother of pearl; *silky,* like satin, due to parallel fibers.

Magnetic. Capable of attracting the magnetic needle or of being attracted by a steel magnet. Some pieces of magnetic minerals will act as magnets themselves, as magnetite, pyrrhotite, and platinum.

Malleable. Capable of being hammered into flat pieces.

Mammillary. Having a smooth surface with rounded hummocky protuberances.

Massive. Without crystal form or faces.

Metallic, Metallodial. See Luster.

Micaceous. Cleaving easily into very thin sheets, like mica.

Nodular. In rounded lumps or nodules.

Oily. See Luster.

Oolitic. Composed of minute rounded grains, like fish roe.

Opalescent. Having a milky or pearly internal reflection.

Parting. A splitting much like cleavage but occurring only at certain irregular intervals, while cleavage can be produced as readily at one point as another.

Pearly. See Luster.

Phosphorescent. Giving off light when gently heated—below red heat.

Pinacoidal. Parallel to the faces of a pinacoid, as cleavage.

Pisolitic. Consisting of rounded particles about the size of peas.

Prismatic. Parallel to the faces of a prism, as cleavage; also said of crystals that are elongated in one direction.

Pseudomorphic. Having the crystal form of another mineral, owing to alteration, replacement, etc.

Pyramidal. Parallel to pyramid faces, as cleavage; or having faces that meet in a point.

Pyroelectric. Becoming electric so as to attract minute particles of tissue paper and other light bodies when moderately heated. A small fragment of the mineral is generally best.

Radiated. Having fibers, columns, or plates diverging from a central point.

Reniform. Having a smooth, rounded, kidney-like surface.

Resinous. See Luster.

Reticulated. Slender crystals crossing like the meshes of a net.

Sectile. Slices or shavings may be cut off with a knife.

Silky. See Luster.

Specific Gravity. Weight compared with an equal volume of water; thus a mineral of G. 2.5 is two and a half times as

heavy as water. When the weight of a mineral in air is a, and its weight in water is w, $G = \frac{a}{a-w}$. A chemical balance may be used or one specially designed for this purpose. Whether a mineral is high or low specific gravity or intermediate can generally be judged by the hand without weighing.

Splendent. Having a brilliant luster.

Splintery. See Fracture.

Stalactitic. In icicle-like pendant forms.

Streak. The color of the fine powder of a mineral or of the mark it will make on a harder white substance. The streak plate of dull white porcelain is convenient for testing minerals below 5.5 in hardness. The same result is obtained by grinding a particle of the mineral in a mortar or between hammer and anvil, if these are entirely clean and free from rust.

Striated. Marked with fine parallel lines or grooves.

Submetallic. See Luster.

Tabular. In broad flattened crystals.

Tarnish. A color different from the fresh mineral, caused by alteration of the surface.

Uneven. See Fracture.

Vitreous. See Luster.

CHEMICAL ELEMENTS

Symbol.	Element.	Atomic Weight.	Symbol.	Element.	Atomic Weight.
A	Argon..............	39.88	Ho	Holmium...........	163.45
Ag	Silver (Argentum)....	107.88	I	Iodine..............	126.92
Al	Aluminum..........	27.1	In	Indium.............	114.8
As	Arsenic.............	74.96	Ir	Iridium.............	193.1
Au	Gold (Aurum).......	197.2	K	Potassium (Kalium)..	39.10
B	Boron..............	11.0	Kr	Krypton............	82.9
Ba	Barium.............	137.37	La	Lanthanum.........	139.0
Be	Beryllium (see Glucinum).		Li	Lithium............	6.94
			Lu	Lutecium...........	174.0
Bi	Bismuth............	208.0	Mg	Magnesium.........	24.32
Br	Bromine............	79.92	Mn	Manganese..........	54.93
C	Carbon.............	12.00	Mo	Molybdenum........	96.0
Ca	Calcium............	40.07	N	Nitrogen............	14.01
Cb	Columbium.........	93.5	Na	Sodium (Natrium)....	23.00
Cd	Cadmium...........	112.40	Nb	Niobium (see Columbium).	
Ce	Cerium.............	140.25			
Cl	Chlorine............	35.46	Nd	Neodymium.........	144.3
Co	Cobalt..............	58.97	Ne	Neon..............	20.2
Cr	Chromium..........	52.0	Ni	Nickel.............	58.68
Cs	Caesium............	132.81	Nt	Niton..............	222.4
Cu	Copper (Cuprum)....	63.57	O	Oxygen.............	16.000
Dy	Dysprosium.........	162.5	Os	Osmium............	190.9
Er	Erbium.............	167.7	P	Phosphorus.........	31.04
Eu	Europium...........	152.0	Pb	Lead (Plumbum)....	207.10
F	Fluorine............	19.0	Pd	Palladium...........	106.7
Fe	Iron (Ferrum).......	55.84	Pr	Praseodymium.......	140.6
Ga	Gallium.............	69.9	Pt	Platinum...........	195.2
Gd	Gadolinium.........	157.3	Ra	Radium.............	226.4
Ge	Germanium.........	72.5	Rb	Rubidium...........	85.45
Gl	Glucinum...........	9.1	Rh	Rhodium...........	102.9
H	Hydrogen...........	1.008	Ru	Ruthenium..........	101.7
He	Helium.............	3.99	S	Sulphur............	32.07
Hg	Mercury (Hydrargyrum)............	200.6	Sb	Antimony (Stibium)..	120.2
			Sc	Scandium...........	44.1

CHEMICAL ELEMENTS—*Continued*

Symbol.	Element.	Atomic Weight.	Symbol.	Element.	Atomic Weight.
Se	Selenium	79.2	Tu	Thulium	168.5
Si	Silicon	28.3	U	Uranium	238.5
Sm	Samarium	150.4	V	Vanadium	51.0
Sn	Tin (Stannum)	119.0	W	Tungsten (Wolframium)	184.0
Sr	Strontium	87.63	X	Xenon	130.2
Ta	Tantalum	181.5	Y	Yttrium	89.0
Tb	Terbium	159.2	Yb	Ytterbium	172.0
Te	Tellurium	127.5	Zn	Zinc	65.37
Th	Thorium	232.4	Zr	Zirconium	90.6
Ti	Titanium	48.1			
Tl	Thallium	204.0			

ABBREVIATIONS

The meaning of most of the abbreviations is obvious, but they are listed here for reference in case of doubt.

abund.	abundant
acic.	acicular
adamant.	adamantine
alk.	alkaline
am.	ammonia
am.mol.	ammonium molybdate
amorph.	amorphous
amt.	amount
anhydr.	anhydrous
Ap.I, II	Appendix I or II to Dana's "System of Mineralogy"
at.wt.	atomic weight
b.b.	before the blowpipe
bd.	bead
blk., blkh.	black, blackish
bot.	botryoidal
bp.	blowpipe
brn., brnh.	brown, brownish
C., cleav.	cleavage
capil.	capillary
ch.	charcoal

col.	color, colored
cols.	colorless
conc.	concentrated
conch.	conchoidal
cp.	compare
c.t.	closed tube
dif.	difficultly
dil.	dilute
disting.	distinguished
dk.	dark
dodec.	dodecahedral
efferv.	effervesces, effervescence
F., fract.	fracture
fibr.	fibrous
flex.	flexible
fol.	foliated
fus.	fuses, fusion, fusibility
G., sp.g.	specific gravity
gel.	gelatinizes, gelatinous
gran.	granular
grn., grnh.	green, greenish
gry., gryh.	gray, grayish
H.	hardness
hemimor.	hemimorphic
hex.	hexagonal
ign.	ignition
incrust.	incrustation
intumes.	intumesces, intumescence
iso.	isometric, isomorphic
lamel.	lamellar
lt.	light
mammil.	mammillary
mm.	millimeter (1-25 inch)
mag.	magnetic
mass.	masses, massive
mon.	monoclinic
non-mag.	non-magnetic
non-vol	nonvolatile
oct.	octahedral
o.f.	oxidizing flame
opaq.	opaque
orth.	orthorhombic
o.t.	open tube
P., part.	parting
per.	perfect

phys.	physical
pinac.	pinacoidal
ppt.	precipitate
prism.	prismatic
pseudm.	pseudomorphic
pyr.	pyritohedral
pyram.	pyramidal
rad.	radial, radiating
rdh.	reddish
reac.	reacts, reaction
res.	residue, resinous
r.f.	reducing flame
rhom.	rhombohedral
S.	Dana's "System of Mineralogy"
sil.	silica (SiO_2)
sol.	soluble, solution
somet.	sometimes
sp.g., G.	specific gravity
s.ph.	sodium metaphosphate
splint.	splintery
st.	streak
subl.	sublimate
submet.	submetallic
T.	Dana's "Textbook of Mineralogy
tab.	tabular
tar.	tarnishes, tarnish
temp.	temperature
tetr.	tetragonal
tetrh.	tetrahedral
transp.	transparent, transparency
transl.	translucent, translucence
tri.	triclinic
us.	usually
vesic.	vesicular
vitr.	vitreous
vol.	volatilizes, volatile
w.	with
wh., whh.	white, whitish
xl., xls.	crystal, crystals
xln.	crystalline, crystallization
yel., yelh.	yellow, yellowish

LABORATORY RULES AND SUGGESTIONS

In laboratory work in mineralogy there are few exceptions to the following rules:

(1) Never break a crystal nor separate one from its matrix. Use the tables beginning on p. 135.

(2) Never scratch a crystal (or any good specimen) more than necessary to determine hardness, and do this in the way that will least disfigure the specimen.

(3) Never break a good specimen if there are enough fragments for tests. When necessary to break it, hold the specimen firmly in the hand so as to catch the fragments in the palm and strike a quick, sharp blow with a light hammer on an edge or corner.

(4) Never heat in the Pt forceps a mineral of metallic luster nor one that yields a metal on charcoal.

(5) Never use grains larger than a pin head when heating a mineral alone on charcoal, and use only as many as can be heated thoroughly.

(6) In beginning an acid test use only the finest powder and barely enough to be seen distinctly. Add more and larger fragments if the reaction is rapid.

(7) Never fill a test tube to a depth greater than its diameter with acid or other reagent, if it is to be boiled.

(8) Dilute HCl (that is, conc. HCl and water in equal parts) should always be used unless some other acid is specified. In many tests the concentrated acid will not yield as good results.

PRECAUTIONS CONCERNING THE USE OF TABLES

(1) All tests should be made upon fresh material, preferably crystalline. If an impurity is known to be present, its effect must be carefully allowed for and not attributed to the mineral.

(2) All tests must be made with care and only clear, decided reactions taken into account. Weak, uncertain results may be due either to a small amount of some impurity or to careless or hasty manipulation.

(3) Physical properties, such as luster, color, and hardness, must be determined on clean, fresh surfaces.

Hardness and specific gravity of powdery or earthy minerals cannot be determined satisfactorily by the ordinary laboratory methods; and furthermore such minerals are generally dull or have but little luster.

(4) The powdered mineral to be used in the various tests should be prepared by crushing and grinding (not pounding) small grains of pure material in an agate mortar (if not harder than 6.5) or under a hammer on any clean surface of iron or steel. If the mineral is rare and but little can be used for determination a steel "diamond" mortar may be used, or fragments may be wrapped in 2 or 3 folds of paper and pounded with a hammer.

(5) The tables are constructed on the plan of eliminating one group of minerals after another until the proper species is found; hence the order as given must be followed strictly, both in the general table and in the sections to which it refers.

(6) Each test should be recorded as soon as made whether results are negative or positive. This may be done in systematic order in a notebook, as suggested on page 65*a*.

As a Reference Book. In referring to the tables for information it should be borne in mind that the tests and characters leading up to each section are an essential part of the description of every mineral in the section. These are given in abbreviated form at the beginning of each section and are set forth more fully on the reverse side of the sheet.

DETERMINATIVE TABLES

GENERAL TABLE

(Special attention is called to the *precautions* on the preceding page.)

	Section	Page
I. Metallic or Submetallic Luster.		
The streak is black or dark colored.		
A. Fusible, at least on thin edges (fus. 1–5), or volatile.		
1. Arsenic minerals.—A white sublimate forms on charcoal far from the assay; usually also gives a garlic odor..	1	66
2. Antimony minerals.—A dense white sublimate forms on the charcoal near the assay..................	2	68
3. Sulphides not previously included.—Fumes of sulphur dioxide are given in the open tube, if not on charcoal, and acid reaction on moist blue litmus paper placed in the upper end of the tube....................	3	70
4. Not previously included..........................	4	72
B. Infusible or nearly so (fus. above 5).		
1. Iron minerals.—Become strongly magnetic after heating in the reducing flame and cooling............	5	76
2. Manganese minerals.—A minute quantity gives a manganese reaction in soda or borax bead; soluble in hydrochloric acid with evolution of chlorine gas....	6	78
3. Not previously included..........................	7	78
II. Without Metallic Luster.		
The streak is light-colored or white.		
A. Easily volatile or combustible..........................	8	80
B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.		
Part I. Give a globule of metal when fused with an equal volume of powdered charcoal and 3 times its volume of soda on charcoal.		
1. Lead minerals.—Globules of lead and a yellow coating. With "bismuth flux" a chrome-yellow coat, darker while hot..................................	9	82
2. Copper minerals.—Globule of copper; copper reactions in acids...	10	84
3. Silver minerals.—Silver globule, brittle when containing antimony..................................	11	84
4. Bismuth minerals.—Brittle bismuth globules and yellow sublimate. A red sublimate with "bismuth flux"..	12	86

Part II. Become magnetic after heating in the reducing flame and cooling. Iron, cobalt, and nickel minerals.		
1. Soluble in hydrochloric acid without residue* or gelatinous silica upon evaporation	13	86
2. Soluble in hydrochloric acid with the formation of gelatinous silica or decomposed with separation of silica	14	88
3. Insoluble in hydrochloric acid or nearly so	15	90
Part III. Not included in the foregoing parts I and II.		
1. Alkaline reaction on moist turmeric paper after intense ignition.		
a. Easily and completely soluble in water	16	92
b. Insoluble in water or slowly or partially soluble	17	94
2. Soluble in hydrochloric acid without residue* or gelatinous silica upon evaporation	18	96
3. Soluble in hydrochloric acid with the formation of gelatinous silica upon evaporation.		
a. Give water in the closed tube	19	98
b. Little or no water given off in the closed tube	20	100
4. Decomposed by hydrochloric acid with separation of silica but without complete solution or the formation of jelly.		
a. Give water in the closed tube	21	102
b. Little or no water in the closed tube	22	104
5. Insoluble in hydrochloric acid or nearly so	23	106
C. Infusible or nearly so (fus. above 5).		
1. Alkaline reaction on moist turmeric paper after intense ignition	24	116
2. Soluble in hydrochloric acid without residue* or the formation of gelatinous silica upon evaporation	25	118
3. Soluble in hydrochloric acid with the formation of gelatinous silica upon evaporation	26	120
4. Decomposed by hydrochloric acid with separation of silica but without complete solution or the formation of jelly	27	122
5. Insoluble in hydrochloric acid or nearly so.		
a. Can be scratched with a knife; not so hard as glass	28	124
b. Cannot be scratched with a knife; as hard as glass or harder	29	126

* This is on the assumption that only the pure mineral is being tested. It often happens, however, that insoluble impurities are present, either as inclusions in crystals or in admixture with granular and earthy minerals. Such impurities must be carefully looked for, and due allowance must be made for them when their presence is known.

LABORATORY RECORDS

For each mineral determined record should be made of tests and diagnostic characters, in the order in which they are met in the tables. Small loose-leaf note-books, with paper about $3\frac{1}{2}$ by $5\frac{1}{2}$ inches, furnish ample space and have been found most convenient for this purpose. The record of the determination of orthoclase may be taken as an illustration.

No. 64

Luster vitr. to pearly
St. wh. Fus. 5
No metal w. powd. ch. and soda
Not mag. or alk. on ign.
Insol. in HCl

(*Sec. 23, p. 106*)

Not micaceous or foliated
2 cl. about 90°
Pale red. H. 6. G. 2.56
K flame w. gypsum
Cl. faces not striated

ORTHOCLASE $KAlSi_3O_8$

Uses: Pottery mfr.

J. R. Brown

Mar. 12, 1915

Such records are particularly useful in case of error, and the separation into two parts, belonging to the general and the special tables, respectively, is also an advantage. The condensed skeleton form saves much of the student's and instructor's time without sacrificing clearness.

Emphasis should be placed on the necessity of recording each test immediately upon its completion.

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SECTION 1

I. Metallic or Submetallic Luster. Streak black or dark-colored.

A. Fusible, at least on thin edges (fus. 1–5), or volatile.

1. Arsenic minerals.—A white sublimate on charcoal far from the assay; usually also a garlic odor.

		Name.	Composition.
Mag. globule on ch.	As and S reac. in o.t. As in c.t.	**ARSENOPYRITE** (Mispickel) T303 S97	FeAsS (Co iso. w. Fe)
	As, but little or no S	Löllingite (Leucopyrite) T303 S96	$FeAs_2$ to Fe_2As_4
Cu flame on ch. after roasting and moistening with HCl. SO_2 fumes in o.t.	Disting. by phys.properties. (Cp. tetrahedrite)	**Enargite** T315 S147	Cu_3AsS_4
		TENNANTITE T313 S137	$Cu_8As_2S_7$ (Ag, Zn, Fe, Sb, iso.
	Ag w. soda on ch. (Cp. polybasite)	**Pearceite** T 315 Ap.I. 50	$(Ag,Cu)_9AsS_6$
Cu flame on ch. as above; no SO_2 fumes in o.t.	Disting. by phys.properties. All tar. to bnh. color. Whitneyite is rdh. on rubbed surface and malleable	Domeykite T286 S44	Cu_3As
		Algodonite T286 S45	Cu_6As
		Whitneyite T286 S45	Cu_9As
Co in borax bd. after roasting. Rose col. sol. in conc. HNO_3. (Cp. Ni minerals, below.)	As subl. in c.t.	**Smaltite** T301 S87	$CoAs_2$ (Fe, Ni iso. w. Co)
	As and S reac. in o.t.	**Cobaltite** T301 S89	CoAsS (Fe iso. w. Co)
		Glaucodot T304 S101	(Co,Fe)AsS
Ni in borax bd. after roasting. (May be masked by Co.) Apple-grn. sol. in HNO_3 and dimethylglyoxime test for Ni (see Nickel (3))	As subl. in c.t.	**Chloanthite** T301 S88	$NiAs_2$ (Fe, Co iso. w. Ni)
	As in c.t. on intense ign.	**Niccolite** (Copper Nickel) T295 S71	NiAs (Fe, Co iso. w. Ni)
	As and S reac. in o.t.	**Gersdorffite** T302 S90	NiAsS (Fe, Co iso. w. Ni)
Vol. on ch. without fusion	As subl. in c.t.	**Arsenic** T274 S11	As (Sb iso. w. As)
Pt sponge in o.t. (Heat gently at first.)	Pt insol in any single acid	Sperrylite T302 S92	$PtAs_2$

Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Ag-wh. to Fe-gry.	Blk.	5.5–6	5.9–6.2	2	Orth.; us. xls.	C. prism. F. uneven
Ag-wh. to steel-gry.	Blk.	5–5.5	7.0–7.4	2	Orth.; us. mass.	C. basal F. uneven
Gryh-blk.	Gry-blk.	3	4.43–4.45	1	Orth.; us. xls.	C. prism., per. F. uneven
Dk. Pb-gry. to Fe-blk.	Blk. to dk. cherry-red	3–4	4.37–4.49	1.5	Iso. tetrh.; xls. & mass.	F. uneven
Blk.	Blk.	3	6.12–6.17	1	Mon.; tabular & mass.	F. conch.
Sn-wh. to steel-gry.	Gry.	3–3.5	7.2–7.75	2	Massive	F. uneven
Steel-gry.	Gry.	4	7.62	2	Massive	F. uneven
Pale rdh. to gryh-wh.	Ag-wh.	3.5	8.4–8.6	2	Massive	Malleable F. hackly
Sn-wh.	Blk.	5.5–6	6.4–6.6	2.5	Iso. pyr.; us. mass.	C. oct. F. uneven
Ag-wh to gry. w. rdh. tone	Blk.	5.5	6–6.3	2–3	Iso. pyr.; us. xls.	C. cubic, per. F. uneven
Gryh-wh.	Blk.	5	5.90–6.01	2–3	Orth.	C. basal F. uneven
Sn-wh.	Gryh-blk.	5.5–6	6.4–6.6	2	Iso. pyr.; us. mass.	C. oct. F. uneven
Pale Cu-red.	Pale brnh-blk.	5–5.5	7.33–7.67	2	Hex.; us. mass.	F. uneven
Sn-wh.	Blk.	5.5	5.6–6.2	2	Iso. pyr.; us. mass.	C. cubic F. uneven
Sn-wh.; tar. dk. gry.	Gry.	3.5	5.63–5.73	Vol.	Hex. rhom.; us. gran.	C. basal, per.
Sn-wh.	Blk.	6–7	10.60	2	Iso. pyr.	F. conch.

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SECTION 2

I. Metallic or Submetallic Luster. Streak black or dark-colored.

A. Fusible, at least on thin edges (fus. 1–5), or volatile.

2. Antimony minerals.—A dense white sublimate forms on the charcoal near the assay.

		Name.	Composition.
Easily and completely vol. on ch.; no Pb reac.	Wh. slowly vol. subl. in o.t.	**Antimony** T275 S12	Sb
	SO_2 and wh. non-vol. subl. in o.t.	**STIBNITE** (Antimony Glance) T283 S36	Sb_2S_3
Pb reac. after roasting and fus. on ch. w. "bismuth flux"	Ag reac. with HNO_3 sol.	Freieslebenite T309 S124	$(Pb,Ag_2)_5Sb_4S_{11}$
	Cu reac. with HNO_3 sol.; steel-gry.	**Bournonite** T310 S126	$(Pb,Cu_2)_3Sb_2S_6$
	No Ag or Cu. Disting. by xln. and phys. characters	**Jamesonite** (Feather Ore) T308 S122	$Pb_2Sb_2S_5$
		Zinkenite T307 S112	$PbSb_2S_4$
		Boulangerite T309 S129	$Pb_5Sb_4S_{11}$
Ag reac. in HNO_3 sol. w. HCl; no Pb. Ag globule after roasting and fus. w. soda on ch. Subl. red to lilac when only Ag, Sb, and S are present	Cu reac. in HNO_3 sol.; gry.	**Freibergite** (Ag Tetrahedrite) T313 S137	$(Cu,Ag)_8Sb_2S_7$ (Fe, Zn iso. w. Cu_2)
	Deep red to blk.; st. Indian-red	**Pyrargyrite** (Ruby Silver: Dark Red Silver Ore) T311 S131	Ag_3SbS_3
	Blk., stout 6-sided (orth.) prisms	**Stephanite** (Brittle Silver Ore) T314 S143	Ag_5SbS_4
	Blk., 6-sided (mon.) plates; triangular markings on basal plane	**Polybasite** T314 S146	$(Ag,Cu)_9SbS_6$ (As iso. w. Sb)
	Sb and Ag reac. No S	Dyscrasite T286 S42	Ag_3Sb
Cu reac. in HNO_3 sol. No Pb or Ag globule w. soda on ch.	May contain Pb, Ag, Zn, Fe, and As	**TETRAHEDRITE** (Gray Copper) T312 S137	$Cu_8Sb_2S_7$ (Fe, Zn, Pb, Ag iso. w Cu; As iso. w. Sb)

Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Sn-wh.	Sn-wh.	3–3.5	6.64–6.72	1	Hex. rhom.; us. mass.	C. basal, per.
Pb-gry.	Pb-gry.	2	4.52–4.62	1	Orth.; us. xls.	C. pinac. per. F. uneven
Steel-gry.	Steel-gry.	2–2.5	6.2–6.4	1	Mon.	F. uneven
Steel-gry.	Fe-gry.	2.5–3	5.7–5.9	1	Orth.; us. xls.	F. uneven
Blkh-gry.	Gryh-blk.	2–3	5.5–6.0	1	Orth.; us. capil.	C. basal, per. F. uneven
Steel-gry.	Steel-gry.	3–3.5	5.30–5.35	1	Orth.	F. uneven
Bluish Pb-gry.	Blk.	2.5–3	5.75–6.0	1	Orth.	F. smooth
Steel-gry.	Blk., often rdh.	3–4	4.85–5.0	1.5	Iso. tetrh.	F. uneven
Deep red to blk.	Purplish red	2.5	5.77–5.86	1	Hex. rhom.; hemimor.	C. rhom. F. conch.
Fe-blk.	Fe-blk.	2–2.5	6.2–6.3	1	Orth.	F. uneven
Fe-blk.	Blk.	2–3	6–6.2	1	Mon.	F. uneven
Ag-wh.	Ag-wh.	3.5–4	9.44–9.85	1.5	Orth.; us. massive	C. basal
Gry. to Fe-blk.	Gry. to Fe-blk.	3–4	4.4–5.1	1.5	Iso. tetrh., Fig. 27	F. uneven

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SECTION 3

I. Metallic or Submetallic Luster. Streak black or dark-colored.

A. Fusible, at least on thin edges (fus. 1–5), or volatile.

3. Sulphides without As or Sb.—Fumes of SO_2 in open tube, if not on charcoal, and acid reaction on moist litmus paper placed in the upper end of the tube.

			Name.	Composition.
Ag globule in o.f. on ch.	Contains only Ag and S. Sectile		**Argentite** (Silver Glance) T288 S46	Ag_2S
Pb globule and yel. subl. on ch.	No Bi		**GALENA** (Galenite) T287 S48	PbS
Cu flame on ch. after roasting and moistening w. HCl	Mag. in o.f. (Stannite only after long ign.)	Brass-yel.	**CHALCOPYRITE** (Copper Pyrites) T297 S80	$CuFeS_2$
		Brnh-bronze, purple tar.	**BORNITE** (Peacock Ore) T297 S77	Cu_3FeS_3
		Steel-gry.; wh. subl. in o.f.	**Stannite** (Tin Pyrites) T315 S83	Cu_2FeSnS_4 (Sn iso. w. Fe)
	Not mag. in o.f.	Cu in r.f. after roasting. Covellite much S in c.t., Chalcocite none	**CHALCOCITE** (Copper Glance) T290 S55	Cu_2S
			Covellite T294 S68	CuS
		Ag reac. in HNO_3 sol.	**Stromeyerite** T 290 S56	$(Ag,Cu)_2S$
Mag. in o.f.; no Cu. Contains Fe, Co or Ni	Pale brass-yel. Completely sol. in cold conc. HNO_3		**PYRITE** (Iron Pyrites; Fool's Gold) T300 S84	FeS_2
	Pale brass-yel. to wh. S separates from cold conc. HNO_3 sol.		**MARCASITE** (White Iron Pyrites) T302 S94	FeS_2
	Brnh-bronze; us. mag.; st. blk.		**PYRRHOTITE** (Magnetic Pyrites; Mundic) T296 S73	FeS (Ni iso. w. Fe) S in sol. up to 6%
	Zn reac. w. soda on ch. Submetallic luster		**SPHALERITE** (Zinc Blende; Black Jack) T291 S59	ZnS (Fe, Mn iso. w. Zn)
	Ni in borax bd. after roasting. HNO_3 sol. grn. Millerite capillary xls. or velvety crusts; Pentlandite gives Fe ppt. w. am. from HNO_3 sol.		**Millerite** (Hair Pyrites). T295 S70	NiS
			Pentlandite T293 S65	(Fe,Ni)S
	Co in borax bd. after roasting. HNO_3 sol. rose col.		**Linnaeite** T297 S78	$(Co,Ni)_3S_4$ (Fe, Cu iso. w. Co)
	Ag globule w. borax on ch. Flakes flexible		Sternbergite T290 S57	$AgFe_2S_3$

Color.	Streak.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
Blkh-gry.	Blkh-gry.	2–2.5	7.2–7.36	1.5	Iso.	F. conch.
Pb-gry.	Pb-gry.	2.5	7.4–7.6	2	Iso.; us. xls. or gran.	C. cubic, per.
Brass-yel.	Grnh-blk.	3.5–4	4.1–4.3	2	Tet. sphenoid-al; us. mass.	F. uneven
Brnh-red bronze Purplish tar.	Pale gryh-blk.	3	4.9–5.4	2.5	Iso.; us. mass.	F. uneven
Steel-gry. to Fe-blk.	Blkh.	4	4.3–4.5	1.5	Iso. tetrh.; us. mass.	F. uneven
Dk. Pb-gry. Blkh. tar.	Dk. Pb-gry.	2.5–3	5–5.8	2–2.5	Orth.; us. mass.	F. uneven
Indigo-blue	Pb-gry. to blk.	1.5–2	4.59–4.64	2.5	Hex.; us. mass.	C. basal, per.
Dk. steel-gry.	Dk. steel-gry.	2.5–3	6.15–6.3	1.5	Orth.; us. mass.	F. uneven
Pale brass-yel.	Grnh-blk. to brnh-blk.	6–6.5	4.95–5.10	2.5–3	Iso. pyr. Figs. 28, 30	F. uneven
Pale yel. to almost wh.	Gryh. or brnh-blk.	6–6.5	4.85–4.90	2.5–3	Orth.; tabular; pryam.	F. uneven
Yelh-brh. bronze	Blk.	3.5–4.5	4.58–4.65	2.5–3	Hex.; us. mass.	P. basal F. uneven
Dk. brn. to blk.	Lt. to dk. brn.	3.5–4	3.9–4.1	5	Iso. tetr.; us. mass.	C. dodec., per.
Brass-yel.	Grnh-blk.	3–3.5	5.3–5.65	1.5–2	Hex.rhom.; us. capil.	C. rhom. F. uneven
Lt. bronze yel.	Lt. bronze to brn.	3.5–4	4.6	1.5–2	Iso.	C. oct. F. uneven
Pale steel-gry.; tar. Cu-red	Gryh-blk.	5.5	4.8–5	2	Iso.	F. uneven
Brnh-bronze	Blk.	1–1.5	4.1–4.22	1.5	Orth.	C. basa·, per.

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SECTION 3—*Concluded*

I. Metallic or Submetallic Luster. Streak black or dark-colored.

A. Fusible, at least on thin edges (fus. 1–5), or volatile.

3. Sulphides without As or Sb.—Fumes of SO_2 in open tube, if not on charcoal, and acid reaction on moist litmus paper placed in the upper end of the tube.

SECTION 4

I. Metallic or Submetallic Luster. Streak black or dark-colored.

A. Fusible, at least on thin edges (fus. 1–5), or volatile.

4. Little or no As, Sb or S.

		Name.	Composition.
Bi reac. w. "bismuth flux"	Te reac. w. H_2SO_4	**Tetradymite** T284 S39	$Bi_2(Te,S)_3$
	Contains only Bi and S	**Bismuthinite** (Bismuth Glance) T284 S38	Bi_2S_3
Mn in borax bd. after roasting	H_2S in HCl	**Alabandite** T292 S64	MnS
Rdh-violet sol. when gently heated in conc. H_2SO_4.—Tellurium minerals.		See page 74.	

SEC. 4. Metallic luster; st. da

			Name	Composition
Native metal, malleable		Cu reac. w. HNO_3 sol.	**COPPER** T278 S20	Cu
		Ag reac. w. HNO_3 sol. (Cp. amalgam below)	**SILVER** T278 S19	Ag (Somet. w. Au, Cu, H
		Insol. in HNO_3; us. some Ag	**GOLD** T275 S14	Au (Us. w. some Ag)
		Insol. in HNO_3; much Ag	**ELECTRUM** T276 S15	(Au,Ag)
		Grnh-yel. subl. w. "bismuth flux" on ch.	Lead T279 S24	Pb
Native metal, brittle or liquid		Bright red subl. on ch. w. "bismuth flux"	**Bismuth** T275 S13	Bi
		Hg subl. in c.t.; amalgam leaves Ag res.	Mercury (Quicksilver) T279 S22	Hg
			Amalgam T279 S23	(Ag,Hg)
Mag. or becomes so in r.f. Contains Fe (Cp. the dark micas, sec. 23, which are sometimes submetallic)	Little or no H_2O in c.t.	Strongly mag. before heating	**MAGNETITE** (Magnetic Iron Ore; Lodestone) T339 S224	$FeFe_2O_4$ (Somet. Mg, Mn, Ti)
		Nonmag. or but slightly so before heating	**HEMATITE** (Specular Iron) T334 S213	Fe_2O_3
	(Continued next page)		Martite T336 S216	Fe_2O_3

Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Pale-steel gry.	Gry.	1.5–2	7.2–7.6	1.5	Hex.rhom.; us. bladed.	C. basal per. Laminae flex.
Lt. Pb-gry.	Lt. Pb-gry.	2	6.4–6.5	1	Orth.; us. mass.	C. pinac., per.
Fe-blk. Brn. tar.	Olive-grn.	3.5–4	3.95–4.04	3	Iso. tetr.; us. mass.	C. cubic, per.

k; fus. 1–5 or vol.; no As, Sb or S.

Cu-red, Tar. blk.	Cu-red, shiny	2.5–3	8.8–8.9	3	Iso.; us. mass.	F. hackly
Ag-wh.; tar. gry. to blk.	Ag-wh., shiny	2.5–3	10.1–11.1	2	Iso.; us. acic. plates or mass.	F. hackly
Au-yel	Au-yel., shiny	2.5–3	15.6–19.33	2.5–3	Iso.; us. mass.	F. hackly
Yelh-wh.	Yelh-wh., shiny	2.5–3	12.5–15.5	2–2.5	Iso.	F. hackly
Pb-gry.	Pb-gry., shiny	1.5	11.37	1	Iso.; us.plates and globular	F. hackly
Ag-wh., rdh. hue	Ag-wh., shiny	2–2.5	9.7–9.83	1	Hex. rhom.; us. gran.	C. basal, per.
Sn-wh.	....	......	13.596	Vol.	Liquid	
Ag-wh.	Ag-wh., shiny	3–3.5	13.75–14.1	....	Iso.	F. uneven
Fe-black	Blk.	5.5–6.5	5.17–5.18	5–5.5	Iso.; xls., mass.	F. uneven P. oct.
Steel-gry. to Fe-blk.	Dk. red to brnh-red	5.5–6.5	4.9–5.3	5–5.5	Hex. rhom.	F. uneven P. bas. or rhom.
Fe-blk.	Rdh-brn. to purplish-brn.	6–7	4.8–5.3	5–5.5	Iso.	F. conch. P. oct.

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SECTION 4—*Continued*

I. Metallic or Submetallic Luster. Streak black or dark-colored.

A. Fusible, at least on thin edges (fus. 1–5), or volatile.

4. Little or no As, Sb or S.

			Name.	Composition.
	Much H_2O in c.t.	Botryoidal, stalactitic, amorphous	LIMONITE (Brown Hematite; Bog Iron Ore) T350 S250	$Fe_2(OH)_6Fe_2O_3$
		Prismatic xls.	GOETHITE (Göthite) T349 S247	FeO(OH)
		Rdh-blk.; st. dark rdh-brn.	TURGITE (Hydrohematite) T350 S245	$[(FeO(OH)]_2Fe_2$ C
Cu globule in r.f. on ch.		Cuprite submetallic luster; Tenorite in scales or earthy	CUPRITE T331 S206	Cu_2O
			Tenorite (Melaconite; Paramelaconite) T332 S209	CuO
W reac. after fus. w. soda Mag. w. little soda		Mn in soda bd. (Cp. hübnerite)	WOLFRAMITE T539 S982	$(Fe,Mn)WO_4$
		Little or no Mn reac.	Ferberite S985	$FeWO_4$
Mn in borax bd.		Slowly sol. in HCl w. a little gel. sil.	Braunite T343 S232	$3MnMnO_3.MnSiO$
Cb reac. after fus. w. borax		Mn in soda bd. Mag. w. little soda	COLUMBITE T490 S731	$(Fe,Mn)Cb_2O_6$
		Mn in soda bd.; U in s. ph. bd.	Samarskite T492 S739	$R''_3R'''_2(Nb,Ta)_6C$ R'' = Fe, Ca, UO_2 R''' = Ce and Y meta
Gel. sil. in HCl sol. on evaporation		Fus. w. much intumes. Insol. in HCl after fus.	Allanite (Orthite) T440 S522	$R''_2R'''_3(OH)(SiO$ R'' = Ca and Fe R''' = Al, Fe, & Ce me
		Strongly mag. after fus. Little intumes.	Ilvaite (Lievrite) T445 S541	$CaFe_2(FeOH)(SiO$
Te minerals Gently heated in conc. H_2SO_4 gives rdh-violet sol.	Fus. and wholly vol.	Wh. subl. near assay; grn. flame	Tellurium T275 S11	Te
	Ag globule in o.f.	May contain Au also	Hessite T289 S47	Ag_2Te (Au iso. w. Ag)
	Au w. soda on Ch. Us. w. some Ag (Continued next page)	Slightly sectile to brittle	Petzite T289 S48	$(Ag,Au)_2Te$
		Very brittle; cleavable. Krennerite decrepitates violently b.b.	Sylvanite T304 S103	$(Au,Ag)Te_2$
			Krennerite T305 S105	$(Au,Ag)Te_2$

	Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Dk. brn., blk., yel.	Yelh-brn.	5–5.5	3.6–4	5–5.5	Fibr.; mass.	F. splintery
	Yelh. or redh-brn. to blk.	Yelh-brn.	5–5.5	4–4.4	5–5.5	Orth.; us. prisms	C. pinac., per.
$'_3$	Rdh-blk.	Dk. rdh-brn.	5.5–6	4.14–4.6	5–5.5	Botry.; incrust.	F. splintery
	Deep red	Brnh-red	3.5–4	5.85–6.15	2.5–3	Iso.	F. conch. or uneven
	Fe-gry. to blk.	Gryh-blk.	3–4	5.82–6.25	3	Mon.; mass.	C. basal, per. F. conch. to uneven
	Dk. gryh-blk. to brnh-blk.	Blk.	5–5.5	7.2–7.5	3–3.5	Mon.; us. xls.	C. pinac., per. F. uneven
	Blk.	Brnh-blk.	4–4.5	6.8–7.11	3.5	Mon.	C. pinac., per F. uneven
$'_3$	Dk. brnh-blk. to steel-gry.	Brnh-blk. to steel-gry.	6–6.5	4.75–4.82	4.5–5	Tetr.	C. pyram., per. F. uneven
	Fe-blk. to brnh-blk.	Dk. red to blk.	6	5.3–7.3	5–5.5	Orth.; us. xls.	F. uneven
$)_{21}$ ıls	Velvet-blk.	Dk. rdh.-brn.	5–6	5.6–5.8	4.5–5	Orth.; us. mass.	F. conch.
$)_3$ ıtals	Brn. to pitch-blk	Gry.	5.5–6	3–4.2	2.5	Mon.; us. mass.	F. uneven to conch.
$'_4)_2$	Fe-blk.	Blk.	5.5–6	3.99–4.05	2.5	Orth.; us. prism.	F. uneven
	Sn-wh.	Sn-wh.	2–2.5	6.1–6.3	1	Hex. rhom.; us. mass.	C. prism., per.
	Steel-gry. to Pb-gry.	Gry.	2.5–3	8.3–8.5	1	Iso.; us. mass.	F. uneven
	Steel-gry. to Fe-blk.	Gry.	2.5–3	8.7–9.02	1.5	Massive	F. uneven
	Steel-gry. to Ag-wh.	Gry.	1.5–2	7.9–8.3	1	Mon.	C. pinac., per. F. uneven
	Ag-wh. to brass-yel.	Gry.	2.5	8.35	1	Orth.; us. prism.	C. basal, per.

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SECTION 4—*Concluded*

I. Metallic or Submetallic Luster. Streak black or dark-colored.

A. Fusible, at least on thin edges (fus. 1–5), or volatile.

4. Little or no As, Sb or S.

SECTION 5

I. Metallic or Submetallic Luster. Streak black or dark-colored.

B. Infusible or nearly so (fus. above 5).

1. Iron minerals.—Become strongly magnetic after heating in the reducing flame and cooling.

			Name.	Composition.
		Very brittle; uneven to conchoidal fract.	**Calaverite** T305 S105	(Au,Ag)Te_2
	Bi w. soda on ch.	Red subl. on ch. w. "bismuth flux"	**Tetradymite** T284 S39	Bi_2Te_3 (S iso. w. Te)
	Pb w. soda on ch.	$PbSO_4$ ppt. w. H_2SO_4 in HNO_3 sol.	Altaite T288 S51	PbTe
			Nagyagite T305 S105	Au, Pb, Sb, Te, S

SEC. 5. Metallic luster; st. dark; fu

Strongly mag. before heating. (Cp. platinum, which is sometimes mag.)	Completely sol. in HCl; sol. reac. for both ferrous and ferric Fe. (Cp. ilmenite, below)	**MAGNETITE** (Magnetic Iron Ore; Lodestone) T339 S224	$FeFe_2O_4$ (Somet. Mg, Mn, Ti
	Malleable. Meteoric Fe and some terrestrial Fe contains Ni	**Iron** (Meteoric Iron) T281 S28	Fe (Us. w. some Ni)
Ti in s. ph. bd. w. Sn on ch.	Disting. by xln. and phys. properties; ilmenite somet. slightly mag.	**ILMENITE** (Menaccanite; Titanic Iron) T336 S217	$FeTiO_3$ (Often also Fe_2O_3: so Mg)
		Pseudobrookite T343 S232	$Fe_4(TiO_4)_3$
Cr in s.ph. bead	Bead shows Fe reac. while hot and Cr on cooling	**CHROMITE** (Chromic Iron) T341 S228	$FeCr_2O_4$ (Mg iso. w. Fe; Al Fe''' iso. w. Cr
Mn in soda bd.	Wh. ZnO subl. on intense ign. w. soda, borax, and powdered ch. on ch.; grn. w. $Co(NO_3)_2$	**FRANKLINITE** T341 S227	(Fe,Zn,Mn) $(Fe,Mn)_2O_4$
Little or no H_2O in c.t.	Sometimes slightly mag. before heating. Dif. fus.	**HEMATITE** (Specular Iron) T334 S213	Fe_2O_3
		Martite T336 S216	Fe_2O_3
H_2O in c.t. Dif. fus.	Mammillary, botryoidal, stalactitic, amorphous	**LIMONITE** (Brown Hematite; Bog Iron Ore) T350 S250	$Fe_2(OH)_6Fe_2O_3$
	Us. prisms	**GOETHITE** (Göthite) T349 S247	FeO(OH)
	Us. decrepitates violently in c.t.	**Turgite** (Hydrohematite) T350 S245	$[FeO(OH)]_2Fe_2O_3$

Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Pale bronze-yel.	Yelh-gry.	2.5	9.04	1	Massive	F. uneven
Pale steel-gry.	Gry.	1.5–2	7.2–7.6	1.5	Hex. rhom.; us. bladed	C. basal., per. Laminæ flex.
Sn-wh.; tar. bronze-yel.	Gry.	3	8.16	1.5	Iso.; us. mass.	C. cubic
Dk. Pb-gry.	Dk. Pb-gry.	1–1.5	6.85–7.2	1.5	Orth.; us. fol.	C. pinac., per. Laminæ flex.

above 5; becomes strongly mag. in r.f.

Fe-blk.	Blk.	5.5–6.5	5.17–5.18		Iso.; xls., mass.	P. oct. F. uneven
Steel-gry.	Steel-gry.	4–5	7.3–7.8		Iso.; us. mass.	C. cubic F. hackly
Fe-blk.	Blk. to brnh-red	5–6	4.5–5		Hex. rhom.; us. plates or mass.	F. conch.
Dk. brn. to blk.	Yelh. or rdh-brn.	6	4.4–4.98		Orth.	F. uneven
Fe-blk. to brnh.-blk.	Dk. brn.	5.5	4.32–4.57		Iso.; us. mass.	F. uneven.
Fe-blk.	Rdh-brn. to blk.	5.5–6.5	5.07–5.22		Iso.; gran., mass.	P. oct. F. uneven
Steel-gry. to Fe-blk. Earthy, red	Cherry-rd brnh-red	5.5–6.5	4.9–5.3		Hex. rhom.	F. uneven, scaly, or fibr.
Fe-blk.	Purplish or rdh-brn.	6–7	4.8–5.3		Iso.; us. xls.	P. oct. F. conch.
Brn. to blk. Earthy, yel.	Yelh-brn. Yel. ocher	5–5.5	3.6–4		No xls.; us. mass. or fibr.	F. splintery
Dk. brn. to blk.	Brnh-yel. to ocher-yel.	5–5.5	4.0–4.4		Orth.; us. prisms	C. pinac., per. F. uneven
Blk. to rdh-blk.	Brnh-red	5.5–6	4.14–4.6		Mass. or mammil.	F. splint.

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SECTION 6

I. Metallic or Submetallic Luster. Streak black or dark-colored.

B. Infusible or nearly so (fus. above 5).

2. Manganese minerals.—A minute quantity gives a Mn reaction in soda or borax bead; soluble in HCl with evolution of Cl gas.

SECTION 7

I. Metallic or Submetallic Luster. Streak black or dark-colored.

B. Infusible or nearly so (fus. above 5).

3. Not magnetic after heating in reducing flame; no Mn reaction in borax bead.

		Name.	Compositi
Little or no H_2O in c. t.	O in c.t.	**PYROLUSITE** T347 S243	MnO_2 (A little H_2O)
	Slowly sol. in HCl w. gel. sil.	**Braunite** T343 S232	$3MnMnO_3.MnSi$
	No gel. sil.	**Hausmannite** T342 S230	Mn_3O_4
Much H_2O in c.t.	Prismatic xls.; us. striated	**MANGANITE** T349 S248	MnO(OH)
	Amorphous; us. Ba reac. in HCl sol. Botry., reniform, stalactitic	**PSILOMELANE** T352 S257	$(H_2,Mn)_2MnO_5$
	Dull, earthy, frothy, powdery, or reniform and compact	**WAD** (Bog Manganese) T352 S257	MnO, MnO_2,H_2O (Often Fe, Si, Al, B

SEC. 7. Metallic luster; st. dark; fus. abov

Very soft. Soils fingers and marks paper easily	S and Mo reac. in o.t. Yel-grn. flame	**MOLYBDENITE** T285 S41	MoS_2
	No reac. in o.t. Very refractory b.b.	**GRAPHITE** (Plumbago; Black Lead) T273 S7	C
Cr in borax or s. ph. bd.	Mag. on intense ign. w. equal amt. of soda on ch. (except varieties with much Mg and Al)	**CHROMITE** (Chromic Iron) T341 S228	$FeCr_2O_4$ (Mg iso. w. Fe; Al a Fe''' iso. w. Cr)
Ti reac. in s. ph. bd. on ch. w. Sn; or in HCl sol. after fus. w. borax	Mag. on intense ign. w. equal amt. of soda on ch.	**ILMENITE** (Menaccanite; Titanic Iron) T336 S217	$FeTiO_3$ (Some Fe_2O_3 and M
	Submetallic to adamantine luster; us. prismatic xls.	**RUTILE** T345 S237	TiO_2 (Us. a little Fe)
	Similar to Rutile. Disting. by xl. habit and phys. properties. Brookite us. tabular xls.	**Octahedrite** T346 S240	TiO_2
		Brookite T347 S242	TiO_2
	Ca reac. in HCl sol. after fus. w. soda and precipitating Ti w. am.	**Perovskite** (Perofskite) T487 S722	$CaTiO_3$ (Fe iso. w. Ca)

n.	Color.	Streak.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Fe-blk.	Blk.	2–2.5	4.73–4.86	Pseudm., mass.	F. splint.
)ı	Dk. brnh-blk. to steel-gry.	Brnh-blk.	6–6.5	4.75–4.82	Tetr.; us. pyram.	C. pyram., per. F. uneven
	Brnh-blk.	Chestnut-brn.	5–5.5	4.72–4.856	Tetr.; us. pyram.	C. basal F. uneven
	Steel-gry. to Fe-blk.	Rdh-brn. to blk.	4	4.2–4.4	Orth.; prism.	C. pinac., per. F. uneven
	Fe-blk.	Brnh-blk.	5–6	3.7–4.7	Massive	F. uneven
ı)	Bluish or brnh-blk. to dull blk.	Brnh-blk. to blk.	1–6	3–4.26	Amorph.	F. uneven

e 5; not mag. after r.f.; no Mn in borax bead.

	Pb-gry.	Gryh-blk., grnh. on glazed paper	1–1.5	4.7–4.8	Hex.(?); fol.	C. basal, per.; flex.
	Fe-blk. to dk. steel-gry.	Gryh.-blk.	1–2	2.09–2.23	Hex. rhom.; fol.	C. basal, per.; flex.
ıd	Fe-blk. to brnh-blk.	Dk. brn.	5.5	4.32–4.57	Iso.; us. mass.	F. uneven
ı)	Fe-blk.	Brnh-red to blk.	5–6	4.5–5	Hex. rhom.; us. mass. or plates	F. conch.
	Rdh-brn. to blk. and yelh.	Pale brn.	6–6.5	4.18–4.25	Tetr.; us. xls.	C. prism. F. uneven
	Brn. to dk. blue and blk.	Cols.	5.5–6	3.82–3.95	Tetr.; us. pyram.	C. basal and pyram. F. conch.
	Hair brn. to blk.	Cols. to gryh. or yelh.	5.5–6	3.87–4.08	Orth.; us. xls.	F. uneven
	Yel. and brn. to blk.	Cols. to gryh.	5.5	4.017–4.039	Iso.	C. cubic F. uneven

SECTION 7—*Concluded*

I. Metallic or Submetallic Luster. Streak black or dark-colored.

B. Infusible or nearly so (fus. above 5).

3. Not magnetic after heating in reducing flame; no Mn reaction in borax bead.

SECTION 8

II. Luster not Metallic. Streak light-colored or white.

A. Easily volatile or combustible.

		Name.	Composition.
Cb reac. after fus. w. soda or borax, dissolving in HCl, and boiling w. Sn	W. little soda becomes mag.; us. Mn reac. also	**COLUMBITE** T490 S731	$(Fe,Mn)Cb_2O_6$ (Ta iso. w. Cb; a litt Sn and W)
		Tantalite T490 S731	$(Fe,Mn)Ta_2O_6$ (Cb iso. w. Ta; sligl Sn and W)
	Disting. by st. and dull exterior	**Fergusonite** T490 S729	$Y(Cb,Ta)O_4$ (Er, Ce, U iso. w. Y)
	H_2O in c.t.; turns yel.	Yttrotantalite T492 S738	$(Ca,Fe)(Y,Er)(Ta,Cb)_4O_{15}.4H_2O$ (Also us. Ce, U, and
U in s. ph. bd. Little or no Cb	Very heavy; sol. in dil. H_2SO_4 w. slight evolution of gas (He)	**Uraninite** (Pitchblende) T521 S889	Uranate of Pb and (Also Th, La, Y, Ca, He, A, and us. H_2O
Pt or metals of the Pt group [Cp. sperrylite (Sec. 1) and the black micas (Sec. 23)].	Malleable; b.b. unaltered; sometimes mag.	**Platinum** T280 S25	Pt (Us. w. Fe, Ir, Os)
	Slightly malleable to brittle; Os in o.t.	Iridosmine (Osmiridium) T280 S27	(Ir,Os) (Somet. Rh, Pt, Ru)
	No reac. for Os	Iridium T280 S27	Ir (W. Pt, Os, etc.)

SEC. 8. Nonmetallic luster; st.

Burns w. blue flame and SO_2 fumes	Subl. in c.t. is red liquid while hot, yel. solid when cold	**SULPHUR** T273 S8	S (Us. clay, bitumen, et
As_2O_3 subl. on ch.; wh. xln., vol.; far from assay	Subl. in c.t. deep red, nearly blk. when hot; a rdh-yel. transp. solid when cold	**REALGAR** T282 S33	AsS
		ORPIMENT T282 S35	As_2S_3
	Vol. on ch.; As_2O_3, subl. in c.t.	Arsenolite T330 S198	As_2O_3
Sb_2O_3 subl. on ch.; dense wh. and near assay	SO_2 in o.t.	**Kermesite** T305 S106	Sb_2S_2O
	Easily fus. in c.t. w. slight wh. subl.	**Senarmontite** T330 S198	Sb_2O_3
		Valentinite T330 S199	Sb_2O_3

	Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
le	Fe-blk. to gryh. and brnh-blk.	Dk. red to blk.	6	5.3–6.5		Orth.; us. prisms	F. uneven
te	Blk.	Blk.	6	6.5–7.3		Orth.	
	Brnh-blk.	Pale brn.	5.5–6	4.3–5.8		Tetr.; us. lamellar	F. uneven
n)	Yel. to brn. and blk.	Cols. to gry.	5–5.5	5.5–5.9		Orth.; us. prisms	F. conch.
U N.)	Gryh., grnh., or brnh-blk.	Brnh-blk.	5.5	9–9.7		Iso.; us. mass.	F. conch., uneven
	Whh.steel-gry.	Gry., shiny	4–4.5	14–19		Iso.; us. grains or scales	F. hackly
	Sn-wh. to lt. steel-gry.	Gry.	6–7	19.5–21.2		Hex. rhom.; us. flat grains	C. basal, per.
	Ag-wh., tinge of yel.	Gry.	6–7	22.6–22.8		Iso.	F. hackly

light; easily vol. or combustible.

	Color.	Luster	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
.)	Pale yel. to brnh. and grnh-yel.	Resinous	1.5–2.5	2.05–2.09	1	Orth. Figs. 56, 57	F. conch. to uneven
	Aurora-red & orange-yel.	Resinous	1.5–2	3.556	1	Mon.; us. xls.	C. pinac. F. conch.
	Lemon-yel.	C. pearly; resinous	1.5–2	3.4–3.5	1	Mon.; us. fol.	C. pinac., per.; striated; flex.
	Cols. to wh.	Vitreous or silky	1.5	3.70–3.72	1	Iso; us. capil.	F. uneven
	Cherry-red to brnh-red	Adamantine	1–1.5	4.5–4.6	1	Mon.; us. acic.	C. pinac., per.
	Cols. to wh. and gryh.	Resinous	2–2.5	5.22–5.3	1.5	Iso.	F. uneven
	Cols. to wh., rdh., or brnh.	Adamantine C. pearly	2.5–3	5.566	1.5	Orth.; us. prism.	C. pinac., per., also prism.

SECTION 8—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

A. Easily volatile or combustible.

SECTION 9

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part I. Gives a globule of metal when fused on charcoal with an equal volume of powdered charcoal and 3 times its volume of soda.

1. Lead minerals.—Globules of Pb and a yellow coating; with "bismuth flux" a chrome-yellow coat, darker while hot.

		Name.	Composition.
Hg subl. in c.t. w. soda that has been dried by previously heating nearly to redness	SO_2 and Hg in o.t.; blk. subl. in c.t.	**CINNABAR** T293 S66	HgS (Us. w. Fe_2O_3, clay, bi men)
	Cl reac. w. $AgNO_3$ after soda fus.	Calomel T317 S153	Hg_2Cl_2
K or Na flame color; sol. in H_2O	Alkaline residue after ign.; wholly vol. only by prolonged heating	Section 16	

SEC. 9. Nonmetallic luster; st. light; fu

CO_2 efferv. in warm dil. acids	In c.t. dark yel. while hot; us. decrepitates	**CERUSITE** T363 S286	$PbCO_3$
	In c.t. wh. $PbCl_2$ subl. which fus. to cols.	Phosgenite T364 S292	$(PbCl)_2CO_3$
	HCl sol. w. $BaCl_2$ gives wh. ppt. $BaSO_4$	Leadhillite T529 S921	$Pb_2(PbOH)_2(CO_3)_2S$
S. reac. in fus. w. soda; sol. in dil. HCl; $PbCl_2$ ppt. on cooling	Little or no H_2O in c.t.	**ANGLESITE** T527 S907	$PbSO_4$
	H_2O in c.t.; Cu reac. in HCl sol.	**Linarite** T530 S927	$[(Pb,Cu)OH]_2SO_4$
		Caledonite T530 S924	$[(Pb,Cu)OH]_2SO_4$
HNO_3 sol. reacts for P w. am. mol.	In c.t. slight wh. subl. $PbCl_2$	**PYROMORPHITE** T499 S770	$Pb_4(PbCl)(PO_4)_3$ (Often also Ca and A
As subl. in c.t. w. ch.	Wh. ppt. AgCl w. $AgNO_3$ in HNO_3 sol.	**Mimetite** T500 S771	$Pb_4(PbCl)(AsO_4)_3$ (Often also Ca and I
V in s. ph. bd.	Wh. ppt. AgCl w. $AgNO_3$ in HNO_3 sol.	**Vanadinite** T500 S773	$Pb_4(PbCl)(VO_4)_3$ (Somet. P and As)
	H_2O in c.t. Reacts for Zn. Cuprodescloizite contains Cu	**Descloizite** (Cuprodescloizite) T505 S787	(Pb,Zn)[(Pb,Zn)O V
Cr in s. ph. bd.	St. orange-yel.	**Crocoite** T529 S913	$PbCrO_4$
Mo in s. ph. bd. (in o.f. yelh-grn., in r.f. dark grn.)		**Wulfenite** T541 S989	$PbMoO_4$ (Ca somet. iso. w. Pb
Not included above. In o.f. on ch. fus. to yel. glass; in r.f. globule of metallic Pb without fluxes		Massicot T332 S209	PbO (Us. impure)

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
tu-	Cochineal-red to brnh.	Adamantine	2–2.5	8.0–8.2	Vol. 1.5	Hex. rhom.	C. prism., per. F. uneven
	Cols., wh., or gry.	Adamantine	1–2	6.482	Vol. 1	Tetr.	F. conch. Sectile

us. 1–5; Pb globule w. soda and ch. on ch.

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Cols. to wh. and gry.	Adamantine	3–3.5	6.46–6.57	1.5	Orth.	F. conch.
	Cols., wh., gry. and yel.	Adamantine	2.75–3	6.0–6.3	1	Tetr.; us. xls.	C. prism. and basal
O_4	Cols., wh., yel., grn., or gry.	C. pearly. Resinous	2.5	6.26–6.44	1.5	Mon.; us. tab.	C. basal, per. F. uneven
	Cols., wh., yelh., grnh.	Adamantine to vitreous	2.75–3	6.3–6.39	2.5	Orth.; us. xls.	C. basal and prism. F. conch.
	Azure-blue	Vitreous	2.5	5.3–5.45	1.5	Mon.	C. pinac., per. F. conch.
	Bluish-grn.	Resinous	2.5–3	6.40	1.5	Orth.	C. basal, per.
)	Grn., yel., brn. and wh.	Resinous	3.5–4	6.5–7.1	2	Hex.; us. prism.	F. uneven
)	Cols., yel., orange, brn.	Resinous	3.5	7.0–7.25	1.5	Hex.; us. prism.	F. uneven
	Ruby-red, brn., yel.	Resinous	2.75–3	6.66–7.10	1.5	Hex.; us. prism.	F. uneven
H] O_4	Brnh-blk. to red.	Greasy	3.5	5.9–6.2	1.5	Orth.; us. xls.	F. uneven
	Bright red	Adamantine to vitreous	2.5–3	5.0–6.1	1.5	Mon.; us. xls.	F. uneven
)	Yel., orange-red, gry., wh.	Resinous to adamantine	2.75–3	6.7–7.0	2	Tetr.; us. tab.	C. pyram. F. uneven
	S-yel. to rdh-yel.	Dull	2	7.83–9.36	1.5	Mass., scaly	

SECTION 10

I. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part 1. Gives a globule of metal when fused on charcoal with an equal volume of powdered charcoal and 3 times its volume of soda.

2. Copper minerals.—Globule of Cu; Cu reactions in acids.

SECTION 11

II. Luster not metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part I. Gives a globule of metal when fused on charcoal with an equal volume of powdered charcoal and 3 times its volume of soda.

3. Silver minerals.—Ag globule, brittle when containing Sb.

		Name.	Composition.
Deep red col. (Hydrocuprite orange)	Strong sol. in HCl gives wh. ppt. Cu Cl when much diluted (a cuprous compound)	**CUPRITE** (Hydrocuprite) T331 S206	Cu_2O (OH in hydrocuprite)
CO_2 efferv. in HCl	H_2O in c.t. Disting. by color	**MALACHITE** T364 S294	$(CuOH)_2CO_3$
		AZURITE T365 S295	$Cu(CuOH)_2(CO_3)_2$
Blue flame col.	H_2O in c.t.	**Atacamite** T322 S172	$Cu(CuCl)(OH)_3$
S reac. in fus. w. soda	Much H_2O in c.t. Sol. in H_2O	**Chalcanthite** T534 S944	$CuSO_4.5H_2O$
	Acid H_2O on intense ign. in c.t.	**Brochantite** T530 S925	$[Cu(OH)_2]_3CuSO_4$
As fumes on ch.; As mirror w. ch. in c.t.; deflagrates on ch.	B.b. cracks and fus. Gel. $Al(OH)_3$ ppt. w. am. in HCl sol.	Liroconite T514 S853	$[CuAl(OH)_6]_3Cu_6Al(AsO_4)_5.20H_2O$
	Globule xln. after fus. Euchroite much H_2O in c.t.; others little H_2O at red heat. Disting. by phys. properties	**Clinoclasite** T505 S795	$(CuOH)_3AsO_4$
		Olivenite T504 S784	$Cu(CuOH)AsO_4$
		Euchroite T511 S838	$Cu(CuOH)AsO_4.3H_2O$
	Decrep. and gives much H_2O in c.t.; res. of olive-grn. scales	Chalcophyllite T511 S840	$Cu(OH)_2[(CuOH)_2AsO_4]_2.10H_2O$
P reac. w. am. mol.	U in s. ph. bd. Micaceous	**Torbernite** T515 S856	$Cu(UO_2)_2(PO_4)_2.8H_2O$
	H_2O and blackens in c.t.	**Libethenite** T504 S786	$Cu(CuOH)PO_4$

SEC. 11. Nonmetallic luster; st. light; fus

SO_2 fumes and wh. subl. of As_2O_3 or Sb_2O_3 in c.t. (Cp. polybasite)	Abund. subl. in c.t., deep red hot, rdh-yel. cold; slight S subl. above it	**Proustite** (Ruby Silver) T311 S134	Ag_3AsS_3
	Slight subl. in c.t., blk. hot, red-brn. cold; slight S subl. above it.	**Pyrargyrite** (Ruby Silver; Dark Red Silver Ore) T311 S131	Ag_3SbS_3 (Somet. As iso. w. Sb)

Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Ruby-red to rdh-blk. (Orange)	Adamantine to earthy	3.5–4	5.85–6.15	3	Iso. (Hydrocuprite earthy)	F. conch. or uneven
Bright grn.	Vitreous, silky, or dull	3.5–4	3.9–4.03	3	Mon.; us. botry.	C. basal, per. F. uneven
Azure-blue	Vitreous	3.5–4	3.77–3.83	3	Mon.; us. xls.	F. conch.
Emerald-grn.	Adamantine to vitreous	3–3.5	3.75–3.77	3–4	Orth.; us. prism.	C. pinac., per F. conch.
Deep azure-blue	Vitreous	2.5	2.12–2.30	3	Tri.	F. conch.
Deep emerald grn.	Vitreous	3.5–4	3.907	3.5	Orth.; us. xls.	C. pinac., per. F. uneven
Sky-blue to grnh.	Vitreous	2–2.5	2.882–2.985	3–3.5	Mon.; us. xls.	F. uneven
Dk. grn. to bluish-grn.	Vitreous; C. pearly	2.5–3	4.19–4.37	2–2.5	Mon.	C. basal, per.
Blkh-grn. to olive-grn. and brn.	Vitreous to adamantine	3	4.1–4.4	2–2.5	Orth.; us. prism.	F. conch. to uneven
Emerald-grn.	Vitreous	3.5–4	3.389	2–2.5	Orth.; us. prism.	F. uneven
Grass-grn.	Vitreous; C. pearly	2	2.4–2.66	2–2.5	Hex. rhom.; us. tab.	C. basal, per.
Emerald-grn. to apple-grn.	Vitreous; C. pearly	2–2.5	3.4–3.6	3	Tetr.; us. tab.	C. basal, per.; fol.
Dk-grn. to olive-grn.	Resinous	4	3.6–3.8	2–2.5	Orth.	F. uneven

s. 1–5; Ag globule w. soda and ch. on ch.

Scarlet to ruby-red. St. scarlet	Adamantine	2–2.5	5.55	1	Hex. rhom.; hemimor.	C. rhom. F. conch.
Dk.red to blk. St. purplish	Metallic adamantine	2.5	5.77–5.86	1	Hex. rhom.; hemimor.	C. rhom. F. conch.

SECTION 11—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part I. Gives a globule of metal when fused on charcoal with an equal volume of powdered charcoal and 3 times its volume of soda.

3. Silver minerals.—Ag globule, brittle when containing Sb.

SECTION 12

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part I. Gives a globule of metal when fused on charcoal with an equal volume of powdered charcoal and 3 times its volume of soda.

4. Bismuth minerals.—Brittle Bi globules and yellow sublimate; red subl. with "bismuth flux."

SECTION 13

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part II. Does not give a globule of metal with powdered charcoal and soda; becomes magnetic after heating in reducing flame and cooling. Fe, Co, and Ni minerals.

1. Soluble in HCl without residue or gelatinous silica upon evaporation.

		Name.	Composition.
Cl, Br, or I reac. w. powdered galena in c.t.	Subl. wh. both hot and cold	**Cerargyrite** (Horn Silver) T319 S158	AgCl (Somet. Hg iso. w. A
	Subl. yel. hot, wh. cold. Not disting. by bp. methods	**Embolite** T319 S159	Ag(Cl,Br)
		Bromyrite T319 S159	AgBr
	Subl. orange-red hot, lemon-yel. cold	Iodyrite T319 S160	AgI

SEC. 12. Nonmetallic luster; st. light;

CO_2 efferv. in HCl	H_2O in c.t.	Bismutite T367 S307	$BiOBi(OH)_2CO_3$
Does not efferv.	No H_2O in c.t.	Bismite T330 S200	$Bi(OH)_3$ (Often Fe, etc.)

SEC. 13. Nonmetallic luster; st. light; fus. 1–5; no me

CO_2 efferv. in hot HCl	Becomes blk. and mag. in c.t.	**SIDERITE** (Spathic Iron) T359 S276	$FeCO_3$ (Mg, Mn, Ca iso. w.
Dif. fus.; strongly mag. after heating in r.f.	Little or no H_2O in c.t.; st. red	**HEMATITE** T334 S213	Fe_2O_3 (Somet Ti and Mg)
		Martite T336 S216	Fe_2O_3
	H_2O in c.t. Earthy, mammillary, stalactitic	**LIMONITE** (Brown Hematite; Bog Iron Ore) T350 S250	$Fe_2(OH)_6Fe_2O_3$
	Us. prismatic xls.	**GOETHITE** (Göthite) T349 S247	FeO(OH)
	Us. decrepitates in c.t.	**Turgite** (Hydrohematite) T350 S245	$[FeO(OH)]_2Fe_2O_3$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
z)	Pearl-gry. and grnh. to cols.	Resinous to adamantine	1–1.5	5.552	1	Iso.; us. mass.	F. uneven; sectile
	Grn. or yel.	Resinous to adamantine	1–1.5	5.31–5.81	1	Iso.; us. mass.	F. uneven; sectile
	Grn. or yel.	Resinous to adamantine	2–3	5.8–6.0	1	Iso.; us. mass.	F. uneven; sectile
	Yel. to grnh. and brnh.	Resinous to adamantine	1.5	5.6–5.7	1	Hex.; hemimor.	C. basal, per.; sectile

fus. 1–5; Bi globule w. soda and ch. on ch.

	Wh., grn., yel., gry.	Dull	4–4.5	6.86–7.67	1.5	Amorph., earthy.	
	Wh., straw-yel. to grnh. and gryh.	Dull to adamantine		4.361		Hex. rhom.	C. basal, per.; scaly, earthy.

tal on ch.; mag. after r.f.; sol. in HCl without res. or gel. sil.

'e)	Lt. to dk. brn. and gry.	Vitreous; C. pearly	3.5–4	3.83–3.88	4.5–5	Hex. rhom.; us. xln.	C. rhom., per.
	Brnh-red to blk.	Dull	5.5–6.5	4.9–5.3	5–5.5	Earthy; reniform	F. uneven to splint.
	Fe-blk.	Submetallic to dull	6–7	4.8–5.3	5–5.5	Iso.	P. oct. F. conch.
	Yelh-brn. to dk.brn.	Silky or dull	5–5.5	3.6–4.0	5–5.5	Fibr., mass.	F. splint.
	Yelh-or redh-brn. to blk.	Adamantine to dull	5–5.5	4–4.4	5–5.5	Orth.	C. pinac., per.
	Rdh-blk. St. dk. redh-brn.	Dull, silky to submetal.	5–6	4.14–4.6	5–5.5	Botry.; incrust.	F. splint.

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SECTION 13—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part II. Does not give a globule of metal with powdered charcoal and soda; becomes magnetic after heating in reducing flame and cooling. Fe, Co, and Ni minerals.

1. Soluble in HCl without residue or gelatinous silica upon evaporation.

SECTION 14

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part II. Does not give a globule of metal with powdered charcoal and soda; becomes magnetic after heating in reducing flame and cooling. Fe, Co, and Ni minerals.

2. Soluble in HCl with separation of silica or formation of gelatinous silica upon evaporation.

			Name.	Composition.
Sol. in cold H_2O; wh. ppt. $BaSO_4$ w. $BaCl_2$ in HCl sol. Acid H_2O in c.t.		Ferrous iron only	**Melanterite** (Copperas) T534 S941	$FeSO_4.7H_2O$ (Mg and Mn iso. w. Fe
		Ferric iron only; disting. by phys. characters	**Copiapite** T536 S964	$Fe_2(FeOH)_2(SO_4)_5.17H_2O$
			Coquimbite T535 S956	$Fe_2(SO_4)_3.9H_2O$ (Al iso. w. Fe)
		Ferric Fe only; K flame; little H_2O in c.t.	**Jarosite** T537 S974	$K[Fe(OH)_2]_3(SO_4)_2$ (Na iso. w. K)
P reac. w. am. mol. Ferrous Fe	Mn in borax bd. Little or no H_2O in c.t.	Li flame. (Cp. lithiophylite)	**Triphylite** T496 S756	$LiFePO_4$ (Mn iso. w. Fe)
		F reac. w. $KHSO_4$	**Triplite** T502 S777	$R(RF)PO_4$ (R = Fe, Mn, Ca, Mg)
	Mn in borax bd.; H_2O in c.t.; exfoliates		**Childrenite** T513 S850	$FeAl(OH)_2PO_4.H_2O$ (Mn iso. w. Fe)
	Little or no Mn; whitens w. gentle heat in c.t.		**Vivianite** T508 S814	$Fe_3(PO_4)_2.8H_2O$
P reac. w. am. mol.; ferric Fe; H_2O in c.t.			**Dufrenite** T506 S797	$Fe_2(OH)_3PO_4$
As subl. in c.t. w.ch. fragment	Co in borax bd. after roasting; HCl sol. rose-red (Cp. annabergite, below)		**Erythrite** (Cobalt Bloom) T509 S817	$Co_3(AsO_4)_2.8H_2O$ (Ni, Fe, Ca iso. w. Co)
	Ni in borax bd. after roasting; HCl sol. grn. (Co may mask bd. reac. for Ni)		**Annabergite** (Nickel Bloom) T509 S818	$Ni_3(AsO_4)_2.8H_2O$ (Co iso. w. Ni)
	Ferric but no ferrous Fe; HCl sol. yel.; rdh-brn. ppt. w. am.		**Pharmacosiderite** T513 S847	$Fe(FeOH)_3(AsO_4)_3.6H_2O$
			Scorodite T509 S821	$FeAsO_4.2H_2O$

SEC. 14. Nonmetallic luster; st. light; fus. 1–5; no met

Micaceous, foliated, or scaly. (Cp. micaceous minerals. Section 23)	Gel. sil. w. HCl on evaporation	**LEPIDOMELANE** T470 S634	$(K,H)_2Fe_3(Fe,Al)_4(SiO_4)_5$
	Slightly sol. in HCl w. separation of SiO_2	**BIOTITE** (Black Mica) T467 S627	$(K,H)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$
	Readily sol. in HCl w. separation of SiO_2; sol. reacts for Ti	**Astrophyllite** T487 S719	$R'_4R''_4Ti(SiO_4)_4$ (R' = K, Na, H; R'' = Fe, Mn, Mg, Ca) (Zr iso. w. Si)

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
e)	Apple-grn. to wh.	Vitreous	2	1.89–1.9	1 4.5–5	Mon.	C. basal, per. F. conch.
	S-yel.	Pearly	2.5	2.103	4.5–5	Mon.; us. tab.	C. pinac.
	Wh., yelh., brnh., violet	Vitreous	2–2.5	2.1	4.5–5	Hex. rhom.; us. xls.	F. uneven
	Ocher-yel. to clove-brn.	Vitreous	2.5–3.5	3.15–3.26	4.5	Hex. rhom.; us. xls.	C. basal F. uneven
	Lt. blue, grn. or gry.	Vitreous to resinous	4.5–5	3.49–3.56	1.5	Orth.; us. mass.	C. basal, per. and pinac.
l	Chestnut-brn. to blkh-brn.	Resinous	4.5–5	3.44–3.8	1.5	Mon.; us. mass.	C. 2 at right angles F. uneven
)	Yelh-brn. to brnh-blk.	Vitreous to resinous	4.5–5	3.18–3.24	4	Orth.; us. xls.	F. uneven
	Blue, bluish-grn. to cols.	Vitreous; C. pearly	1.5–2	2.58–2.68	2–2.5	Mon.; us. prism.	C. pinac., per. F. splint.
	Dull olive to blkh-grn.	Silky, weak	3.5–4	3.2–3.4	2.5	Orth. us. fibr.	F. splint.
)	Crimson to peach-red	Dull; vitreous; C. pearly	1.5–2.5	2.948	2	Mon.; us. prism.	C. pinac., per.; sectile
	Apple-grn.	Vitreous	1.5–2.5		4	Mon; us. capil.	C. pinac., per. F. uneven, earthy
	Grn., yel., brn.	Adamantine to greasy	2.5	2.9–3.0	1.5–2	Iso. tetrh.; us. xls.	F. uneven
	Pale grn. or brn.	Vitreous	3.5–4	3.1–3.3	2–2.5	Orth.; us. xls.	F. uneven

al on ch.; mag. after r.f.; sol. in HCl w. gel. or granular sil.

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Blk. to grnh-blk.	Adamantine to pearly	3	3–3.2	4.5–5	Mon.	C. basal, per.; elastic
	Grn. to grnh. or brnh-blk.	Splendent; C. pearly	2.5–3	2.7–3.1	5	Mon.	C. basal, per.; elastic
)	Bronze to golden yel.	Pearly to submetallic	3	3.3–3.4	2.5–3	Orth.	C. pinac., per.; brittle

SECTION 14—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part II. Does not give a globule of metal with powdered charcoal and soda; becomes magnetic after heating in reducing flame and cooling. Fe, Co, and Ni minerals.

2. Soluble in HCl with separation of silica or formation of gelatinous silica upon evaporation.

SECTION 15

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part II. Does not give a globule of metal with powdered charcoal and soda; becomes magnetic after heating in reducing flame and cooling. Fe, Co, and Ni minerals.

3. Insoluble in HCl or nearly so.

		Name.	Composition.
Gel. imperfectly; iso. xls.	Mostly ferric Fe (Cp. Garnets, p. 112)	**ANDRADITE** (Ca-Fe Garnet) T417 S442	$Ca_3Fe_2(SiO_4)_3$ (Fe, Mn, Mg, Ca. iso Ca; Al iso. w. Fe)
Gel.; much ferrous Fe	May be mag. from included magnetite	**Fayalite** T422 S456	Fe_2SiO_4
Gel. sil. w. HCl; both ferrous and ferric Fe	Fuses quietly	**Ilvaite** (Lievrite) T445 S541	$CuFe_2(FeOH)(Si$
	Fus. w. intumes.	**Allanite** (Orthite) T440 S522	$R''R'''_3(OH)(SiO$ (R'' = Ca, Fe; R''' = Fe, Ce, La, Nd, Pr)
H_2S and gel. sil. w. HCl	ZnO subl. on ch. w. soda; grn. w. $Co(NO_3)_2$	Danalite T414 S435	$Gl_3R_3(RS)(SiO_4)_3$ (R = Mn, Fe, Zn)
	Mn in borax bd.; no Zn	Helvite T414 S434	$Gl_3R_3(RS)(SiO_4)_3$ (R = Mn, Fe)

SEC. 15. Nonmetallic luster; st. light; fus. 1–

W reac. after fus. w. soda. Very heavy	Mn in soda bd.	**WOLFRAMITE** T539 S982	$(Mn,Fe)WO_4$
	Little or no Mn reac.	**Ferberite** S985	$FeWO_4$
Micaceous (Cp. micaceous minerals, Section 23)	Easily fus.; Li flame	Zinnwaldite T467 S626	$(K,Li)_3Fe(AlO)Al(F,OH)_2(SiO_4$
	Dif. fus.	**BIOTITE** (Black Mica) T467 S627	$(K.H)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$
Red; isometric	Sol. in HCl w. gel. after fus. (Cp. Garnets, p. 112)	**ALMANDITE** (Fe-Al Garnet) T416 S441	$Fe_3Al_2(SiO_4)_3$ (Mn, Mg, Ca iso. w.
Quietly and dif. fus.	Us. bronzy, metalloidal luster; prism and cl. angles near 90°	**Hypersthene** T385 S348	$(Mg,Fe)SiO_3$
	Prism and cl. angles 54° and 126°; Fe chiefly ferrous; sometimes fibrous (asbestos)	**Anthophyllite** (Asbestos in part) T398 S384	$(Mg,Fe)SiO_3$ (Somet. also Al)
Fus. w. intumes.	Fused mass dk. brn. or blk.	**EPIDOTE** (Pistacite) T438 S516	$Ca_2(AlOH)(Al,Fe$ $(SiO_4)_3$

o metal on ch.; mag. after r.f.; sol. in HCl w. gel. or granular sil.

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
. w.	Wine-red, grnh., yel., brn., to blk.	Vitreous to resinous	6.5–7.5	3.8–3.9	3.5	Iso.	F. uneven to conch.
	Yel. to dk. yelh-grn.	Metalloidal, resinous	6.5	4–4.14	4	Orth.; us. mass.	C. pinac. F. uneven
)$_4$)$_2$	Fe-blk.	Submetallic	5.5–6	3.99–4.05	2.5	Orth.; us. prism.	F. uneven
)$_3$ Al,	Brn. to pitch-blk.	Resinous to submetallic	5.5–6	3.0–4.2	2.5	Mon.; us. mass.	F. uneven to conch.
	Flesh-red to gry.	Vitreous to resinous	5.5–6	3.427	3	Iso. tetrh.; us. mass.	F. uneven
	Yel. to yelh. and redh-brn.	Vitreous to resinous	6–6.5	3.16–3.36	4–5	Iso. tetrh.; us. xls.	F. uneven

; no metal on ch.; mag. after r.f.; insol. in HCl.

	Gryh. to brnh-blk.; st. blk.	Submetallic	5–5.5	7.2–7.5	4	Mon.; us. xls.	C. pinac. per. F. uneven
	Blk. St. brnh-blk.	Submetallic	4–4.5	6.8–7.11	3.5	Mon.	C. pinac. per. F. uneven
)$_2$	Gry., yel., brn., violet	Pearly	2.5–3	2.8–3.2	2.5–3	Mon.	C. basal, per.; flex.
	Grn. to grnh. or brnh-blk.	Splendent C. pearly	2.5–3	2.7–3.1	5	Mon.	C. basal, per.; elastic
Fe)	Deep red to brnh-blk.	Vitreous	6.5–7.5	3.9–4.2	3	Iso.	F. uneven to conch.
	Grnh-blk. to brn. and bronze	Pearly to bronzy	5–6	3.4–3.5	5	Orth.; us. mass.	C. pinac. per. F. uneven
	Gry., clove-brn., grn.	Vitreous C. pearly	5.5–6	3.1–3.2	5–6	Orth.; us. fibr. or mass.	C. prism. per.
)$_2$	Yelh. to blkh-grn. and gry.	Vitreous	6–7	3.25–3.5	3–4	Mon.; us. prism.	C. basal, per. F. uneven

SECTION 15—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part II. Does not give a globule of metal with powdered charcoal and soda; becomes magnetic after heating in reducing flame and cooling. Fe, Co, and Ni minerals.

3. Insoluble in HCl or nearly so.

SECTION 16

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

1. Alkaline reaction on moist turmeric paper after intense ignition.

a. Easily and completely soluble in water.

		Name.	Composition.
Fus. w. intumes.; Na flame	Prism and cl. angles 54° and 126°; Fe chiefly ferrous	Arfvedsonite T405 S401	$[(Na,K)_2,Ca,Fe]Si$ (Some $(Al,Fe)_2O_3$)
	Both ferrous and ferric Fe. Crocidolite is us. fibrous	Crocidolite T404 S400	$NaFe'''(Fe'',Mg)(SiO_3)_2$
		Riebeckite T404 S400	$Na_2Fe'''_2(Fe'',Ca)(SiO_3)_4$
Na flame; fus. quietly	Prism and cl. angles near 90°	**Acmite** (Aegirite) T391 S364	$NaFe'''(SiO_3)_2$
Compare pyroxene, amphibole, tourmaline, chloritoid, and ottrelite, some of the dark green and black varieties of which contain sufficient iron to make them magnetic upon ignition.			

SEC. 16. Nonmetallic luster; st. light; fus. 1–5; no m

Make flame tests below with Pt wire. Most minerals give some yellow color to the fla yellow. The violet flame of K is purplis

			Name	Composition
Wh. AgCl ppt. w. HNO_3 and $AgNO_3$	Wh. $BaSO_4$ ppt. in H_2O sol. w. HCl and $BaCl_2$	K flame	Kainite T530 S918	$MgSO_4.KCl.3H_2O$
		Na flame	Hanksite T530 S920	$9Na_2SO_4.2Na_2CO_3.KCl$
	Intense Na flame; no S		**HALITE** (Rock Salt; Common Salt) T318 S154	NaCl (Us. also Ca and Mg)
	K flame; no S	Little or no H_2O in c.t.	**SYLVITE** T318 S156	KCl (Na iso. w. K)
		Much H_2O in c.t.	**Carnallite** T323 S177	$KMgCl_3.6H_2O$
CO_2 efferv. w. HCl. H_2O sol. gives alkaline reac. w. turmeric paper	Sol. in H_2O of xln. if gently heated in c.t. ($H_2O=63\%$)		**Natron** (Sal Soda) T366 S301	$Na_2CO_3.10H_2O$
	H_2O and CO_2 when gently heated in c.t.		**Trona** T367 S303	$Na_2CO_3 \cdot HNaCO_3 \cdot 2H_2O$

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
O_3	Blk.; st. dk. bluish-gry.	Vitreous	6	3.44–3.45	2.5	Mon.; us. prism.	C. prism., per. F. uneven
	Leek-grn. to deep lavender-blue	Silky, dull	4	3.2–3.3	3.5	Fibrous	Fibrous
	Blk.	Vitreous	6	3.433	3?	Mon.	C. prism., per.
	Grnh. to brnh-blk.	Vitreous	6–6.5	3.50–3.55	3.5	Mon.; prism.	C. prism. F. uneven

etal on ch.; not mag. after r.f.; alk. after ign.; sol. in water.

me, but those containing Na as an essential constituent give an intense and persistent h-red when seen through dark blue glass.

	Cols., wh. to redh.	Vitreous	2.5–3	2.067–2.188	1.5–2	Mon.	C. pinac.
	Cols., wh. to yelh.	Vitreous	3–3.5	2.562	1.5	Hex.; us. xls.	C. basal F. uneven
	Cols., wh., redh., bluish	Vitreous	2.5	2.13	1.5	Iso.; us. cubic	C. cubic, per. F. conch.
	Cols., wh., redh., bluish	Vitreous	2	1.97–1.99	1.5	Iso.	C. cubic, per.
	Cols., wh., redh.	Vitreous to greasy	1	1.6	1–1.5	Orth.; us. mass.	F. conch.
	Cols., gry., wh., yelh.	Vitreous	1–1.5	1.42–1.46	1	Mon.	C. basal F. conch.
	Cols., gry., wh., yelh.	Vitreous	2.5–3	2.11–2.14	1.5	Mon.	C. pinac., per. F. uneven

SECTION 16—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part II. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

1. Alkaline reaction on moist turmeric paper after intense ignition.

a. Easily and completely soluble in water.

SECTION 17

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

1. Alkaline reaction on moist turmeric paper after intense ignition.

b. Insoluble in water or slowly or partially soluble.

		Name.	Composition.
Sulphates.—H_2O sol. w. HCl and $BaCl_2$ gives wh. ppt. $BaSO_4$	Na flame; little or no H_2O in c.t.	**Thenardite** T523 S895	Na_2SO_4
	B.b. swells and gives K flame; H_2O sol. w. HCl and am. gives gel. ppt. of $Al(OH)_3$	**Kalinite** (Potash Alum) T535 S951	$KAl(SO_4)_2.12H_2O$
	Mg reac. w. $Co(NO_3)_2$ on ch.	**Epsomite** (Epsom Salt) T533 S938	$MgSO_4.7H_2O$
	Intense Na flame; much H_2O in c.t.	**Mirabilite** (Glauber Salt) T531 S931	$Na_2SO_4.10H_2O$
Nitrates.—Deflagrates on ch.; NO_2 fumes w. $KHSO_4$ in c.t.	Intense Na flame	**SODA NITER** T517 S870	$NaNO_3$
	K flame	**NITER** (Saltpeter) T517 S 871	KNO_3
	H_2O in c.t.; deliquescent before ign., not after	Nitrocalcite T517 S872	$Ca(NO_3)_2.nH_2O$
B reac. w. turmeric paper	Swells and fus. to clear glass	**BORAX** T520 S886	$Na_2B_4O_7.10H_2O$

SEC. 17. Nonmetallic luster; st. light; fus. 1–5; no me

Make flame tests below with Pt wire and HCl.

CO_2 efferv. in dil. HCl	No H_2O in c.t.; Ba flame		**WITHERITE** T362 S284	$BaCO_3$
	H_2O in c.t.; alkaline sol. in boiling H_2O		**Gay-Lussite** T366 S301	$Na_2Ca(CO_3)_2.5H_2$
S reac. w. powdered ch. and soda on ch.	Much H_2O in c.t. Readily sol. in hot. dil. HCl	Sol. in hot H_2O; no decided flame col.	**GYPSUM** (Selenite; Alabaster) T531 S933	$CaSO_4.2H_2O$
		K flame; Mg reac. w. Na phosphate	**Polyhalite** T535 S950	$K_2Ca_2Mg(SO_4)_4.2H_2O$
	Little or no H_2O in c.t.	Na flame; sol. in HCl	**Glauberite** T523 S898	$Na_2Ca(SO_4)_2$
	(Continued next page)	No flame col.; slowly sol. in hot dil. HCl	**ANHYDRITE** T528 S910	$CaSO_4$

› metal on ch.; not mag. after r.f.; alk. after ign.; sol. in v ate

Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Cols., wh., brnh.	Vitreous	2–3	2.68–2.69	1.5–2	Orth.	C. basal F. uneven
Cols. or wh.	Vitreous	2–2.5	1.75	1	Iso. pyr.; us. fibr.	F. conch.
Cols. or wh.	Vitreous; earthy	2–2.5	1.751	1	Orth.; us. fibr.	C. pinac., per. F. conch.
Cols. or wh.	Vitreous	1.5–2	1.481	1.5	Mon.; us. crusts	C. pinac., per.
Cols. or wh.	Vitreous	1.5–2	2.24–2.29	1	Hex. rhom.; us. incrust.	C. rhom., per.
Cols. or wh.	Vitreous; silky	2	2.09–2.14	1	Orth.; us. acic.	C. prism., per. F. uneven
Wh. or gry.	Silky			2	Fibrous	Fibrous
Cols., wh., gryh.	Vitreous to resinous	2–2.5	1.69–1.72	1–1.5	Mon.; us. prism.	C. pinac., per. F. conch.

tal on ch.; not mag. after r.f.; alk. after ign.; insol. in water.

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Cols., wh., yelh., gryh.	Vitreous	3–3.75	4.27–4.35	2	Orth.; twinned	F. uneven
O	Cols., wh., yelh., gryh.	Vitreous	2–3	1.93–1.95	1.5	Mon.; us. xls.	C. prism. F. conch.
	Cols., wh., yel., red., gry.	Vitreous C. pearly	1.5–2	2.31–2.33	3–3.5	Mon., Figs. 60, 61	C. 3 directions, pinac., per.
	Brick-red to yel.	Vitreous to resinous	2.5–3	2.77–2.78	1.5	Mon.; fibr., lamel.	C. pinac., F. splint.
	Cols., wh., yelh., gryh.	Vitreous	2.5–3	2.70–2.85	1.5–2	Mon.; us. tab.	C. basal, per. F. conch.
	Cols., wh., blue, gry., red	Vitreous; basal cl., pearly	3–3.5	2.90–2.99	3	Orth.; us. mass.	C. pinac., per. 3 directions at 90°

SECTION 17—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

1. Alkaline reaction on moist turmeric paper after intense ignition.

b. Insoluble in water or slowly or partially soluble.

SECTION 18

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

2. Soluble in HCl without residue or gelatinous silica upon evaporation.

			Name.	Composition.
		Sr flame; nearly insol. in HCl	**CELESTITE** T526 S905	$SrSO_4$ (Somet. Ca and Ba)
		Ba flame; nearly insol. in HCl	**BARITE** (Heavy Spar) T524 S899	$BaSO_4$ (Somet. Ca and Sr)
F reac. w. $KHSO_4$ and glass in c.t.	Little or no H_2O in c.t.	Na flame; easily fus.	**CRYOLITE** T321 S166	Na_3AlF_6
		Ca flame; often phosphoresces and decrepitates in c.t.	**FLUORITE** (Fluor Spar) T320 S161	CaF_2 (Somet. Cl iso. w. F)
	Acid H_2O in c.t. Often etches glass and deposits sil.	Stout prisms; us. decrepitates	Thomsenolite T323 S180	$NaCaAlF_6.H_2O$
		Slender prisms; us. decrepitates	Pachnolite T323 S179	$NaCaAl$[illegible]$_2O$

SEC. 18. Nonmetallic luster; st. light; fus. 1–5; no metal on ch.;

H_2S efferv. in hot HCl	Wh. ZnO subl. after intense ign. w. soda; subl. grn. w. $Co(NO_3)_2$			**SPHALERITE** (Zinc Blende) T291 S59	ZnS (Fe, Mn, Cd iso. Zn)
P reac. w. am.mol.	Slight F reac. w. $KHSO_4$ in c.t.	$CaSO_4$ ppt. w. H_2SO_4 in HCl sol.	No H_2O in c.t.	**APATITE** T497 S762	$Ca_4(CaF)(PO_4)_3$ (Cl iso. w. F. Ra Mn)
			A little H_2O HF vapor in c.t.	Herderite T503 S760	$Ca[Gl(OH,F)]PO_4$
		No Ca	Little or no H_2O	Wagnerite T502 S775	$Mg(MgF)PO_4$
	Mn in soda bd.	Li flame	(Cp. triphylite)	**Lithiophylite** T496 S756	$LiMnPO_4$ (Fe iso. w. Mn)
		H_2O in c.t.	No flame color	Purpurite Ap. II, 83	$2(Fe,Mn)PO_4.H_2$(
	U in s.ph. bd.	$CaSO_4$ ppt. w. dil. H_2SO_4 in HCl sol.		**Autunite** T515 S857	$Ca(UO_2)_2(PO_4)_2.8H_2O$
B reac. w. turmeric paper	Na flame	Swells, sol. in H_2O		**BORAX** T520 S886	$Na_2B_4O_7.10H_2O$
(Continued next page)		Ca reac. w. am. oxalate		**Ulexite** (Boronatrocalcite) T520 S887	$NaCaB_5O_9.8H_2O$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Cols., wh., blue, red	Vitreous to pearly	3–3.5	3.95–3.97	3	Orth., Fig. 59	C. basal, per. and prism.
	Cols., wh., blue, yel., red, brn.	Vitreous to pearly	2.5–3.5	4.3–4.6	3	Orth.	C. basal, per. and prism.
	Cols., wh., brnh.	Vitreous to greasy	2.5	2.95–3	1.5	Mon.; us. mass.	C. pinac. F. uneven
	Cols., violet, blue, grn., yel., pink	Vitreous	4	3.01–3.25	3	Iso.; us. cubes.	C. oct., per. F. uneven
f.	Cols., wh., redh.	Pearly to vitreous	2	2.93–3	1.5	Mon.; xls. and mass.	C. basal, per. F. uneven
	C[illegible]r wh.	Vitreous	3	2.93–3	1.5	Mon.; prism.	F. uneven

ιot mag. after r.f; not alk. after ign.; sol. in HCl without res. or gel. sil.

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
v.	Wh., grn., yel., red, brn., blk.	Res. to adamant.	3.5–4	3.9–4.1	5	Iso. tetr.; us. mass.	C. dodec. per., F. conch.
ely	Grn., blue, violet, red, brn., cols.	Vitreous to greasy	4.5–5	3.17–3.23	5–5.5	Hex.	C. bas[illegible] F. unev[illegible]
	Wh. to pale grn. or yel.	Vitreous to resinous	5	2.99–3.01	4	Mon.	F. uneven
	Pale yel., gry. or red	Vitreous	5–5.5	3.07–3.14	3.5–4	Mon.	F. uneven and splint.
	Salmon-color clove-brn.	Vitreous to resinous	4.5–5	3.42–3.56	1.5	Orth.; us. mass.	C. basal, per. and pinac.
	Deep red or redh-purple	Silky	4–4.5	3.40	3–4	Orth.(?); us. mass.	C. pinac. F. uneven
	Lemon-yel. to S-yel.	Adamant. C. pearly	2–2.5	3.05–3.19	2.5	Orth.; tabular	C. basal, per. brittle
	Cols., wh., gryh., bluish, grnh.	Vitreous to resinous	2–2.5	1.69–1.72	1–1.5	Mon.; us. prism.	C. pinac., per. F. conch.
	Wh.	Silky	1	1.65	1	Fibrous	

SECTION 18—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

2. Soluble in HCl without residue or gelatinous silica upon evaporation.

SECTION 19

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

3. Soluble in HCl with the formation of gelatinous silica upon evaporation.

a. Gives water in the closed tube.

			Name.	Composition.
	B flame	No H_2O in c.t.; Cl reac. after fus. w. soda	**Boracite** T518 S879	$Mg_7Cl_2B_{16}O_{30}$
		Slowly vol.; sol. in H_2O	Sassolite (Boric Acid) T352 S255	$B(OH)_3$
		Mn in borax bd.	Sussexite T518 S876	H(Mn,Mg,Zn)BO
		Exfoliates; Ca reac. w. am. oxalate	**Colemanite** T519 S882	$HCa(BO_2)_3.2H_2O$
Mo reac. in s.ph. bd. or H_2SO_4; H_2O in c.t.; on ch. fus. and MoO_3 subl.			Molybdite T330 S201	$Fe_2(MoO_4)_3.7H_2O$
V in s.ph. bd.; H_2O in c.t.; fus. easily to blk. nonmag. slag			**Carnotite** S. Ap. I	K, U, Ca, Ba vanadate
As subl. w. soda and ch. in c.t.	ZnO subl. w. soda on ch.; H_2O in c.t.		**Adamite** T505 S786	$Zn(ZnOH)AsO_4$
	$CaSO_4$ ppt. w. H_2SO_4 in conc. HCl sol.		Pharmacolite T510 S827	$HCaAsO_4.2H_2O$

SEC. 19. Nonmetallic luster; st. light; fus. 1–5; no metal on ch.; ı

Fus. to cols. glass	Intumes.; B flame; H_2O in c.t.	**DATOLITE** T435 S502	$Ca(BOH)SiO_4$
	Intumes.; blebby glass; whitens in c.t.; CO_2 efferv. in warm dil. HCl	**Cancrinite** T411 S427	$H_6Na_6Ca(NaCO_3)Al_6(SiO_4)_9$
	Fus. quietly; whitens in c.t.; little or no Ca after separating Si and Al	**NATROLITE** T461 S600	$Na_2Al(AlO)(SiO_3)_3$ $2H_2O$
Fus. dif. and whitens	**ZnO subl. w. soda on ch.; grn. w. $Co(NO_3)_2$**	**CALAMINE** (Hemimorphite; Smithsonite) T446 S546	$(ZnOH)_2SiO_3$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Cols., wh., yel., gry., grn.	Vitreous	7	2.9–3.0	2	Iso. tetrh.; us. xls.	F. conch.
	Cols., wh., yel., gry.	Pearly	1	1.48	0.5	Tri.; us. tab.	C. basal, per. Unctuous
	Wh., yelh., pinkish	Silky	3	3.42	2	Orth.(?); fibr.	F. splint.
	Cols., wh., yelh., gryh.	Vitr. to adamant	4–4.5	2.42	1.5	Mon.	C. pinac., per. F. uneven
	Straw-yel. to wh.	Silky to adamant.; C. pearly	1–2	4.50	2	Orth. and earthy	C. basal
a-	Canary-yel.	Dull			2.5	Hex.(?); us. earthy	
	Grnh., yelh., redh., violet, cols.	Vitreous	3.5	4.34–4.35	3	Orth.	C. prism. F. uneven
	Wh., gryh., redh.	Vitr. to pearly	2–2.5	2.64–2.73	2.5	Mon.; us. fibr.	C. pinac., per. F. uneven

ıot mag. after r.f.; not alk. after ign.; sol. in HCl w. gel. sil.; water in c.t.

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Cols., grnh., yelh., redh.	Vitreous	5–5.5	2.9–3.0	2–2.5	Mon.; us. xls.	F. conch. to uneven
	Yel., pink, grnh., bluish, gry., wh.	Vitr. to greasy	5–6	2.42–2.50	2	Hex.; us. mass.	C. prism. F. uneven
	Cols., wh., yelh., redh., grnh.	Vitr. to pearly	5–5.5	2.20–2.25	2	Orth.; prism.	C. prism., per. F. uneven
	Wh., grnh., bluish, yelh., brnh.	Vitr. to adamant.	4.5–5	3.40–3.50	6	Orth.; hemimorph.	C. prism., per. F. uneven

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SECTION 19—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

3. Soluble in HCl with the formation of gelatinous silica upon evaporation.

a. Gives water in the closed tube.

SECTION 20

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–3), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

3. Soluble in HCl with the formation of gelatinous silica upon evaporation.

b. Little or no water given off in the closed tube.

SEC. 19.—*Concl.* Nonmetallic luster; st. light; fus. 1–5; no metal on

		Name.	Compositio
Contains Al and Ca (Ppt. by am. and am. oxalate after separating Si; see Silicon (2))	Fus. to blebby enamel; pyroelectric	**Scolecite** T462 S604	$CaAl[Al(OH)_2](SiO_3)_3.2H_2$
	Fus. to wh. vesic. globule; not pyroelectric. Mesolite contains both natrolite and scolecite molecules	**Mesolite** T462 S605	$Na_2Ca_2Al_3(AlO)(SiO_3)_9.8H_2$
		Thomsonite T462 S607	$(Ca,Na_2)_2Al_4(Si$ $5H_2O$
	Fus. to wh. enamel; becomes opaq. and us. crumbles in dry air; us. prismatic xls. w. oblique ends	**Laumontite** T457 S587	$H_4Ca(AlO)_2(SiC$ $2H_2O$
Little or no Al	Fus. to wh. enamel; gives a poor jelly w. HCl.	**Pectolite** T395 S373	$HNaCa_2(SiO_3)_3$

SEC. 20. Nonmetallic luster; st. light; fus. 1–5; no metal on ch.; not m

H_2S in HCl	Na flame; $BaSO_4$ ppt. w. $BaCl_2$ in HCl sol.	**Lazurite** (Lapis Lazuli) T413 S432	$(Na_2,Ca)_2(AlNa$ $Al_2(SiO_4)_3$ (SO_4 iso. w. S_3)
	ZnO subl. on ch. w. soda	Danalite T414 S435	$Gl_3R_3(RS)(SiO_4)$ (R = Mn, Fe, Zn)
	Mn in borax bd.	Helvite T414 S434	$Gl_3R_3(RS)(SiO_4)$ (R = Mn, Fe)
AgCl ppt. w. $AgNO_3$ in HNO_3 sol.; Na flame	Fus. to cols. glass	**Sodalite** T412 S429	$Na_4(AlCl)Al_2(Si$
	Fus. to opaq. grnh. bd.; Zr reac. w. turmeric paper	**Eudialyte** (Eucolite) T407 S409	$Na_4Ca_3Zr(SiO_3)_7$ (Some K, H, Fe, Ce, Cl)
Wh. $BaSO_4$ ppt. w. $BaCl_2$ in dil. HC sol.	Contains much Ca (Ppt. Si and Al first). See Silicon (2)	**Hauynite** (Hauyne) T412 S431	$CaNa_2(AlNaSO_4$ $(SiO_4)_3$
	Contains little or no Ca	**Noselite** (Nosean) T413 S432	$Na_4(AlNaSO_4)Al$ $(SiO_4)_3$
Mn in borax bd. (Cp. willemite)	Wh. ZnO subl. in fine powder on ch. w. soda; grn. w. $Co(NO_3)_2$	TROOSTITE T423 S461	$(Zn,Mn)_2SiO_4$
	Little or no Zn; gel. in cold HCl	**Tephroite** T422 S457	Mn_2SiO_4 (Mg, Fe, Ca, Zn, iso Mn)

.; not mag. after r.f.; not alk. after ign.; sol. in HCl w. gel. sil.; water in c.t.

.	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
	Cols., or wh.	Vitr. or silky	5–5.5	2.16–2.40	2.5	Mon.; us. prism.	C. prism.
	Cols., wh., gry., yel.	Vitr. to silky	5	2.2–2.4	2–2.5	Mon.; acic.	C. prism., per.
)₄.	Cols., wh., grn., brn., gry.	Vitr. to pearly	5–5.5	2.3–2.4	2–2.5	Orth.; us. radial	C. pinac., per. F. uneven
₄.	Wh., yelh., gryh., redh.	Vitr. C. pearly	3.5–4	3.25–3.36	2.5	Mon.; prism.	C. pinac. and prism., per.
	Cols., wh., gryh., redh.	Vitr. or silky	5	2.68–2.78	2	Mon.; us. acic.	C. pinac., per. F. splint.

g. after r.f.; not alk. after ign.; sol. in HCl w. gel. sil.; little or no water in c.t.

)	Deep azure to grnh-blue	Vitreous	5–5.5	2.38–2.45	3	Iso.; us. mass.	F. uneven
	Flesh-red to gry.	Vitr. to res.	5.5–6	3.427	3	Iso. tetrh.; us. mass.	F. uneven
	Yel. to yelh. & redh-brn.	Vitr. to res.	6–6.5	3.16–3.36	3	Iso. tetrh.; us. xls.	F. uneven
)₃	Wh., gry., blue grn., redh.	Vitr. to greasy	5.5–6	2.14–3	3.5–4	Iso.	C. dodec. F. conch.
Mn,	Rose, brnh-red, brn.	Vitreous	5–5.5	2.9–3.0	3	Hex. rhom.	C. basal, per. F. splint.
Al₂	Blue, grn., red, yel., wh.	Vitreous.	5.5–6	2.4–2.5	4.5	Iso.	C. dodec. F. uneven
	Gry., grn., blue, brn., blk.	Vitreous	5.5	2.25–2.40	3.5–4	Iso.	F. uneven
	Apple-grn., flesh-red, brn.	Vitreous	5.5	4.11–4.18	4–4.5	Hex. rhom.; us. mass.	C. basal and prism. F. uneven
w.	Smoky-gry., brnh-red	Vitr. to greasy	5.5–6	4–4.12	3–3.5	Orth.; us. mass.	C. pinac. F. uneven

SECTION 20—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

3. Soluble in HCl with the formation of gelatinous silica upon evaporation.

b. Little or no water given off in the closed tube.

SECTION 21

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

4. Decomposed by HCl with separation of silica but without complete solution or the formation of jelly.

a. Gives water in the closed tube.

		Name.	Composition.
Contain Si, Al, and Ca. See Silicon (2)	Easily sol. in HCl; Na flame	**NEPHELITE** (Elaeolite; Nepheline) T409 S423	Approx. NaAlSiO (Some K and Ca)
	Dif. sol. in HCl; Na flame w. powdered gypsum	**ANORTHITE** (Lime Feldspar) T380 S337	$CaAl_2(SiO_4)_2$
	Fus. w. intumes. to dark slag	**Allanite** (Orthite) T440 S522	$R_2''R_3'''(OH)(SiO$ (R'' = Ca, Fe; R''' = Fe, Ce, Nd, Pr)
	Fus. w. slight intumes. to grnh. or yelh. glass	**Melilite** T426 S474	$Na_2(Ca,Mg)_{11}$ $(Al, Fe)_4(SiO_4)_9$
Not included above	Swells and cracks apart on ign.; often glows	**Gadolinite** T436 S509	$Be_2Fe(YO)_2(SiO_4)$

SEC. 21. Nonmetallic luster; st. light; fus. 1–5; no metal on ch.; not mag. a

Micaceous; flex., but not elastic, or little so	Exfoliates greatly b.b. Hydrated mica	**Vermiculite** (Jefferisite) T476 S664	Hydrous Mg-Al s cate (Also Fe; somet. Na,
Dif. fus.; little or no Al or Ca; much Mg. See Silicon (2)	U. compact grnh. mass.; sometimes fibrous (chrysotile, commercial "asbestos") or foliated (marmolite)	**SERPENTINE** (Chrysotile; Marmolite) T476 S669	$H_4(Mg,Fe)_3Si_2O_9$ (Somet. Ni, iso. w.)
	Somewhat like a gum or resin	**Deweylite** (Gymnite) T479 S676	$H_4Mg_4(SiO_4)_3.2H$ (Somet. Ni iso. w. M
	Compact, fine earthy texture; when dry floats on H_2O	Sepiolite (Meerschaum) T480 S680	$H_4Mg_2Si_3O_{10}$ (Somet. Cu and Ni)
Contains Ca but no Al. See Silicon (2)	Fus. w. intumes. to vesic. enamel; K flame; H_2O in c.t. (16%)	**APOPHYLLITE** T452 S566	$2H_7KCa_4(SiO_3)_8.9H_2O$
	Fus. quietly to wh. enamel; Na flame; little H_2O in c.t. (3%)	**Pectolite** T395 S373	$HNaCa_2(SiO_3)_3$
Becomes opaq. and fus. quietly to clear glass	Na flame; iso., us. trapezohedrons	**ANALCITE** T460 S595	$NaAl(SiO_3)_2.H_2O$
Fus. w. intumes. to blebby enamel	Little H_2O in c.t.; slowly and dif. sol. in HCl; gel. after fus.	**PREHNITE** T442 S530	$H_2Ca_2Al_2(SiO_4)_3$ (Fe iso. w. Al)

mag. after r.f.; not alk. after ign.; sol. in HCl w. gel. sil.; little or no water in c.t.

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
	Cols., gry., grnh., redh., yelh.	Vitr. to greasy	5.5–6	2.55–2.65	3.5	Hex.; hemi-morph.	C. prism. F. uneven
	Cols., wh., gry., redh.	Vitreous	6–6.5	2.74–2.76	4.5	Tri.	C. basal, per. and pinac. F. uneven
)$_3$ Al,	Brn. to blk.	Res., vitr. to sub-met.	5.5–6	3.0–4.2	2.5	Mon.; us. mass.	F. uneven to conch.
	Grn., yel., brn., wh.	Vitr. to res.	5	2.9–3.1	3	Tetr.; us. xls.	C. basal F. uneven
	Grnh. to brnh-blk.	Vitr. to greasy	6.5–7	4.0–4.5	5	Mon.	F. conch., splint.

ter r.f.; not alk. after ign.; decomposed by HCl w. separation of sil.; water in c.t.

ili- K)	Yel., brn., lt. to dk. grn.	Pearly	1–1.5	2.2–2.3	3.5	Mon. (?); fol.	C. basal, per.
Ig)	Olive to blkh-grn., yelh-grn., wh.	Greasy, wax-like, silky	2.5–5 Us. 4	2.5–2.65	5–5.5	Mass.; pseudm.	F. uneven, splint.
O g)	Yel., brn., wh. apple-grn.	Res.	2–3.5	2.0–2.2	4–5	Amorph.	F. uneven, conch.
	Wh. to gryh-wh.	Dull	2–2.5	2.0	5–5.5	Compact; earthy	F. uneven
	Wh., grnh., yelh., redh.	Vitreous; C. pearly	4.5–5	2.3–2.4	1.5	Tetr.; us. xls.	C. basal, per. F. uneven
	Cols., wh., gry.	Vitr.,silky. C. pearly	5	2.68–2.78	2.5–3	Mon.; us. acic.	C. pinac., per. F. splint.
	Cols., wh., yelh., redh.	Vitreous	5–5.5	2.22–2.29	2.5	Iso; us. xls.	F. uneven
	Apple-grn., gry., wh.	Vitreous	6–6.5	2.80–2.95	2	Orth.; us. reni-form or glob-ular	F. uneven

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SECTION 21—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

4. Decomposed by HCl with the separation of silica but without complete solution or the formation of jelly.

a. Gives water in the closed tube.

SECTION 22

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

4. Decomposed by HCl with the separation of silica but without complete solution or the formation of jelly.

b. Little or no water given off in the closed tube.

		Name.	Composition.
Much H_2O in c.t.; contain Al and Ca or Ba See Silicon (2)	Ba reac. w. dil. HCl sol.	**Harmotome** T456 S581	$H_2(Ba,K_2)Al_2(SiO$ $4H_2O$
	Rhom.; fus. w. swelling. Gmelinite often cracks and splits before fus.	**CHABAZITE** T458 S589	$(Ca,Na_2)Al_2(SiO_3)$ $6H_2O$ (Somet. K, Ba, Sr)
		Gmelinite T459 S593	$(Na_2,Ca)Al_2(SiO_3)$ $6H_2O$
	Fus. w. swelling and intumes. Stilbite us. sheaf-like and radiated; xls. seem orth. Cleav. faces of heulandite pearly luster and us. lozenge-shaped	**STILBITE** (Desmine) T456 S583	$H_4(Ca,Na_2)Al_2$ $(SiO_3)_6.4H_2C$
		HEULANDITE T454 S574	$H_4(Ca,Na_2)Al_2$ $(SiO_3)_6.3H_2C$
	Whitens and fus. without swelling to vesic. enamel; K flame with powdered gypsum	**Phillipsite** T455 S579	$2(Ca,K_2,Na_2)Al_2$ $(SiO_3)_4.9H_2$

SEC. 22. Nonmetallic luster; st. light; fus. 1–5; no metal on ch.; not mag. after r.f.;

Ti reac. in HCl sol. w. Sn See Titanium (1)	Fus. w. intumes. to dk. glass	**TITANITE** (Sphene) T485 S712	$CaTiSiO_5$ (Some Fe; somet. Mı
Fus. quietly to glassy globule; slowly sol. in HCl	Us. striated on best cl.; often brilliant play of color	**LABRADORITE** (Ca-Na Feldspar) T379 S334	$n(NaAlSi_3O_8)$ $m(CaAl_2Si_2O_8)$ ($n : m = 1 : 1$ to $1 : 3$
Fus. dif. to wh. globule; rather easily sol. in HCl	HCl sol. gives no Al ppt. w. am.; but Ca reac. w. am. oxalate	**WOLLSATONITE** T394 S371	$CaSiO_3$
Fus. w. intumes. to vesic. glass	Cl reac. w. $AgNO_3$; slowly sol. in acids; Na flame	**WERNERITE** (Scapolite) T425 S468	$n(Ca_4Al_6Si_6O_{25})$ $m(Na_4Al_3Si_9O_{24}Cl)$ $n : m = 3 : 1$ to $1 : 2$)
	Little or no Cl; easily sol. in acids	**Melonite** T425 S467	$Ca_4Al_6Si_6O_{25}$ (Us. some Na)

; mag. after r.f.; not alk. after ign.; decomposed by HCl w. separation of sil.;
r in c.t.

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystallisa-tion.	Cleavage and Fracture.
.	Wh., gry., yel., red, brn.	Vitreous	4.5	2.44–2.50	3.5	Mon.; us. twinned	C. pinac. F. uneven
	Wh., yel., flesh-red	Vitreous	4–5	2.08–2.16	3	Hex. rhom.; xls. nearly cubic	C. rhom. F. uneven
	Wh., yel., flesh-red, grnh.	Vitreous	4.5	2.04–2.17	2.5	Hex. rhom.; us. xls.	C. prism. F. uneven
	Wh., yel., brn., red	Vitreous; C. pearly	3.5–4	2.1–2.2	2–2.5	Mon.; twinned	C. pinac. per. F. uneven
	Wh., yel., gry., red, brn.	Vitreous; C. pearly	3.5–4	2.18–2.22	2–2.5	Mon.	C. pinac. per. F. uneven
	Wh., redh.	Vitreous	4–4.5	2.2	3	Mon.; twinned	C. pinac. F. uneven

not alk. after ign.; decomposed by HCl w. separation of sil.; little or no water in c.t.

)	Gry., brn., yel., grn.	Res. to adamant	5–5.5	3.4–3.56	3	Mon.; us. xls.	C. prism. F. uneven
	Wh., gry., brn., grn.	Vitr. to pearly	5–6	2.70–2.72	3–4	Tri.; us. mass.	C. basal, per. & pinac. F. uneven
	Cols., wh., gry., yel., red, brn.	Vitreous; C. pearly	4.5–5	2.8–2.9	4	Mon.; us. mass.	C. pinac., per. F. uneven
	Wh., gry., grnh., bluish, redh.	Vitr. to pearly	5–6	2.66–2.73	3	Tetr.	C. prism. and pinac. F. uneven
	Cols. to wh.	Vitreous	5.5–6	2.7–2.74	4	Tetr.	C. prism and pinac. F. uneven

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SECTION 23

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

5. Insoluble in HCl or nearly so.

			Name.	Composition.
Micaceous or foliated	Li flame; foliæ elastic	Easily fus. to wh. or gry. globule; acid H_2O in c.t. on intense ign.	**LEPIDOLITE** (Lithia Mica) T467 S624	$LiK[Al(OH,F)_2]Al(SiO_3)_3$
		Easily fus. to dark globule	Zinnwaldite T467 S626	$(K,Li)_3Fe(AlO)[Al(F,OH)_2]Al(SiO$
		Exfoliates greatly; fus. w. dif.; much H_2O in c.t.	Cookeite T467 S625	$Li[Al(F,OH)_2](SiO_3)_2$
	Decomposed by boiling conc. H_2SO_4. (Foliæ lose luster and transp. and acid becomes turbid); foliæ elastic, except chlorite and kämmererite	Us. dk. col.; often w. quartz and feldspar and in igneous rocks.	**BIOTITE** (Black Mica) T467 S627	$(K,H)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$
		Gel. w. HCl.	**LEPIDOMELANE** T470 S634	$(K,H)_2Fe_3(Fe,Al)_4(SiO_4)_5$
		Lt. to dk. col.; us. in xln. limestone; much more readily decomposed than biotite	**PHLOGOPITE** (Magnesia Mica) T469 S632	$[H,K,Mg(F,OH)]_3Mg_3Al(SiO_4)_3$ (A little Fe iso. w. M and Al)
		Foliæ flex. but not elastic; much H_2O	**CHLORITE** (Clinochlore, Penninite, Prochlorite) T472 S643	$H_8(Mg,Fe)_5Al_2Si_3($ (Often a little Cr)
		Col. rdh.; Cr in borax bd.	Kämmererite (Chrome Chlorite) T474 S652	$H_8(Mg,Fe)_5(Al,Cr$ Si_3O_{18}
	Not decomposed by boiling conc. H_2SO_4. (Flakes retain luster and transp., acid remains clear)	Common lt. colored mica; elastic; us. w. quartz and feldspar. Fine scaly us. soapy feel, damourite, sericite, hydromica	**MUSCOVITE** (Potash Mica, Damourite; Sericite, Hydromica) T464 S614	$H_2KAl_3(SiO_4)_3$ (Fe iso. w. Al)
		Na flame	Paragonite (Soda Mica) T467 S623	$H_2NaAl_3(SiO_4)_3$
		Soft; greasy feel; foliæ flex. but not elastic (cp. muscovite, above)	**TALC** (Steatite, Soapstone) T479 S678	$H_2Mg_3(SiO_3)_4$
		Foliæ brittle; harder than true micas	**Margarite** (Brittle Mica) T470 S636	$H_2CaAl_4Si_2O_{12}$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Lilac, gryh-wh., redh., yelh.	Pearly	2.5–4	2.8–2.9	2–2.5	Mon.; us. gran. or scaly	C. basal, per.
)s	Gry., brn., yel., violet	Pearly	2.5–3	2.82–3.2	2–2.5	Mon.	C. basal, per.
	Wh. to yelh-grn.	Pearly	2.5	2.70	4.5–5	Mon.; us. scaly	C. basal, per.
	Grn., yel., brn., blk.	Splendent to pearly and submet.	2.5–3	2.7–3.1	5	Mon.	C. basal, per.
	Blk. to grnh-blk.	Adamant to pearly	3	3–3.2	4.5–5	Mon.	C. basal, per.
. g	Yelh-brn., grn., wh., cols.	Pearly to submet.	2.5–3	2.78–2.85	4.5–5	Mon.	C. basal, per.
ls	Grn. of various shades	Vitr. to pearly	1–2.5	2.6–2.96	5–5.5	Mon.	C. basal, per.
r-	Rose-red to deep red	Vitr. to pearly	2–2.5	2.65–3.1	5–5.5	Mon.	C. basal, per.
	Wh., gryh., yelh., grnh., brnh.	Vitr. to pearly	2–2.5	2.76–3	4.5–5	Mon.	C. basal, per.
	Yelh., grnh., gryh-wh.	Pearly to vitr.	2.5–3	2.78–2.90	5	Mon.; us. scaly, gran.	C. basal, per.
	Apple-grn., gry., wh.	Greasy; C. pearly	1–2.5	2.55–2.80	5	Mon.; us. fol. or mass.	C. basal, per.
	Pink, gry., wh., yelh.	Vitreous; C. pearly	3.5–4.5	2.99–3.08	4–4.5	Mon.	C. basal, per.; brittle

SECTION 23—*Continued*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

5. Insoluble in HCl or nearly so.

			Name.	Composition.
FELDSPARS: 2 cl. at 90° or nearly so; lt. col. Fus. dif. H. near 6 G. 2.5–2.8	K flame. w. powdered gypsum	Microcline may show striations on cl. or xl. faces, but us. not disting. by phys. or bp. characters	**ORTHOCLASE** (Potash Feldspar) T370 S315	$KAlSi_3O_8$ (Na iso. w. K) (Sanidine glassy; w. N
			MICROCLINE T373 S322	$KAlSi_3O_8$ (Na iso. w. K)
	Strong Na flame w. powdered gypsum; little or no K	Us. fine striations on best cleav.; these *Plagioclase Feldspars* form a continuous series from albite to anorthite and are scarcely disting. by bp. methods. Labradorite slightly sol. in HCl; anorthite slowly sol. giving gel. sil.	**ALBITE** (Soda Feldspar) T377 S327	$NaAlSi_3O_8$ (Us. some Ca; often also)
			OLIGOCLASE (Na-Ca Feldspar) T378 S332	$n(NaAlSi_3O_8)$ $m(CaAl_2Si_2O_8)$ ($m : n = 6 : 1$ to $3 : 1$)
			ANDESINE (Na-Ca Feldspar) T379 S333	$n(NaAlSi_3O_8)$ $m(CaAl_2Si_2O_8)$ ($m : n = 3 : 2$ to $1 : 1$)
			LABRADORITE (Ca-Na Feldspar) T379 S334	$n(NaAlSi_3O_8)$ $m(CaAl_2Si_2O_8)$ ($m : n = 3 : 4$ to $1 : 6$)
			ANORTHITE (Lime Feldspar) T380 S337	$CaAl_2Si_2O_8$ (Us. also some Na)
Li flame (sometimes obscured by Na). (Cp. lepidolite)		Swells and fus. to clear or wh. glass. Hiddenite (emerald-green) and kunzite (lilac) are transp.	**SPODUMENE** (Hiddenite; Kunzite) T393 S366	$LiAl(SiO_3)_2$ (Na iso. w. Li)
		Blue phosphorescence with gentle heat. Fus. to wh. enamel	**Petalite** T369 S311	$LiAl(Si_2O_5)_2$ (Na iso. w. Li)
		F reac. w. glass and $KHSO_4$; P reac. after fus. w. soda	**Amblygonite** T503 S781	$Li(AlF)PO_4$ (Na iso. w. Li; OH w.
B flame (Cp. axinite, below)		Rdh. phosphorescence on heating; fus. to cols. glass	**Danburite** T431 S490	$CaB_2(SiO_4)_2$
		Fus. w. intumes. to wh. globule; Cl reac. w. CuO on ch.	**Boracite** T518 S879	$Mg_7Cl_2B_{16}O_{30}$
		Much H_2O in c.t.	Howlite T519 S881	$Ca(BO.OH)_5SiO_4$
B flame w. $KHSO_4$ and fluorite		Fus. w. intumes. and pale B flame	**Axinite** T441 S527	$Ca_7Al_4B_2(SiO_4)_8$ (Mn, Fe, Mg, Zn, H_2 is w. Ca)
		Fus. w. intumes. to blebby glass or slag. Pyroelectric, especially lighter colored varieties. Achroite cols.; indicolite blue; rubellite red	**TOURMALINE** (Schorl; Achroite; Indicolite; Rubellite) T447 S551	$R_{18}(BOH)_2(SiO_5)_4$ (R = Al. Fe, Mg chiefly often some Mn, Ca Na, K, Li, H) (F iso. w. OH)

Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Cols., wh., cream, flesh-red, gry., grn.	Vitreous to pearly	6	2.57	5	Mon.; Figs. 64–66	C. basal, per. and pinac. 90°
Wh., cream, red, grn.	Vitr. to pearly	6–6.5	2.54–2.57	5	Tri.	C. basal, per and pinac. 89°30′
Cols., wh., gry., redh., grn.	Vitreous to pearly	6–6.5	2.62–2.65	4–4.5	Tri.; Fig. 68	C. basal, per. and pinac. 86° 24′
Cols., wh., gry., grnh., bluish, redh. Often a beautiful play of colors on the pinacoid (010)	Vitr. to pearly	6–6.5	2.65–2.67	3.5–4	Tri.; us. mass.	C. basal, per. and pinac. 86° 32′
		5–6	2.68–2.69	3.5–4	Tri.; us. mass.	C. basal, per. and pinac. 86° 14′
		5–6	2.70–2.73	3–3.5	Tri.; us. mass.	C. basal, per. and pinac. 86° 4′
Cols., wh., gry., redh.	Vitr. to pearly	6–6.5	2.74–2.76	4.5–5	Tri.	C. basal, per. and pinac. 85° 50′
Wh., gry., pink., emerald-grn., purple	Vitr. to pearly	6.5–7	3.13–3.20	3.5	Mon.; us. prism.	C. prism. per. F. uneven
Wh., gry., pink, grnh.	Vitreous; C. pearly	6–6.5	2.39–2.46	4	Mon.; us. mass.	C. basal, per. F. uneven
Wh. to pale grn., or blue	Vitr. to greasy; C. pearly	6	3.01–3.09	2	Tri.; us. mass.	C. basal, per. F. uneven
Wh. to pale yel., yelh-brn. & cols.	Vitreous	7–7.25	2.97–3.02	3.5	Orth.	F. uneven
Cols., wh., gry., yel., grn.	Vitreous	7	2.9–3.0	2	Iso. tetrh.; us. xls.	F. conch.
Wh.	Vitreous	3.5	2.55–2.59	2	Nodular, fibrous	F. splint. or smooth
Clove-brn., gry., grn., yel., blk.	Vitreous	6.5–7	3.27–3.35	2–2.5	Tri. Fig. 67	C. pinac. F. conch.
Blk., brn., grn., blue, red, pink wh.	Vitreous to res.	7–7.5	2.98–3.20	3–5 Us. 3	Hex. rhom.; hemimor. Fig. 51	F. conch to uneven

SECTION 23—*Continued*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

5. Insoluble in HCl or nearly so.

			Name.	Composition.
Mn in soda bd.	Gel. w. HCl after fus.; iso. Cp. Garnets, p. 112		**SPESSARTITE** (Mn Garnet) T417 S442	$Mn_3Al_2(SiO_4)_3$ (Us. also Fe and Ca)
	Do not gel. after fus.; 2 cl. nearly 90°	Fus. to nearly blk. glass	**RHODONITE** T395 S378	$MnSiO_3$ (Fe, Ca iso. w. Mn)
		Wh. ZnO subl. w. soda on ch. (slight); grn. w. $Co(NO_3)_2$	Fowlerite (Zn Rhodonite) T396 S378	$(Mn,Zn)SiO_3$ (Fe, Ca, Mg iso. w. M
			Jeffersonite (Mn-Zn Pyroxene) T390 S358	$(Ca,Mn)(Mg,Fe,Zn)(SiO_3)_2$
		Fus. to brnh. glass	Schefferite (Mn Pyroxene) T389 S357	$(Ca,Mn)(Mg,Fe)(SiO_3)_2$
	Fus. w. much intumes. to blk. glass		**Piedmontite** (Mn Epidote) T440 S521	$Ca_2(AlOH)(Al.Mn.Fe)_2(SiO_4)_3$
	C. perf. at 55° and 125° (Amphibole)		Richterite (Mn Amphibole) T401 S391	$(Mg,Mn,Ca,Na_2)_4(SiO_3)_4$
	Cb reac. after fus. w. borax; samarskite gives U reac. in s.ph. bd.		**COLUMBITE** T490 S731	$(Fe,Mn)Cb_2O_6$ (Also Ta, and some Sn and W)
			Samarskite T492 S739	$R_3''R_2'''(Nb,Ta)_6O$ (R'' = Fe, Ca, UO_2; R''' = Ce and Y metals
	W reac. after fus. w. soda	W. little soda on ch. becomes mag. (Cp. ferberite)	**WOLFRAMITE** T539 S982	$(Fe,Mn)WO_4$
		Yel. WO_3 res. on boiling in HCl. Scheelite reacts for Ca w. am. oxalate	**Hübnerite** T539 S982	$MnWO_4$ (Fe iso. w. Mn)
			Scheelite T540 S985	$CaWO_4$ (Us. also Mo; somet. C
Ti reac. in HCl sol. w. Sn See Titanium (1)	Fus. w. slight intumes. to colored glass		**TITANITE** (Sphene) T485 S712	$CaTiSiO_5$ (Some Fe; somet. Mn
			Benitoite Ap. II, 14	$BaTi(SiO_3)_3$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Brnh-red to hyacinth-red	Vitreous	6.5–7.5	4.0–4.3	3	Iso.; us. xls.	F. uneven to conch.
	Rose-red, pink, brn.	Vitreous	5.5–6.5	3.4–3.68	2.5–3	Tri.; us. mass.	C. prism. per. F. uneven
m)	Rose-red	Vitreous	5.5–6.5	3.67	2.5–3	Tri.	C. prism. per. F. uneven
n)	Grnh-blk. to brn.	Vitreous	5–6	3.4–3.6	3–3.5	Mon.	C. prism. F. uneven
	Yelh-brn., redh-brn., blk.	Vitreous	5–6	3.5	4	Mon.	C. prism. F. uneven
	Redh-brn. to redh-blk.	Vitreous	6.5	3.404	3	Mon.	C. basal, per. F. uneven
	Brn., yel., rose-red	Vitreous	5.5–6	3.09	4	Mon.; prism.	C. prism., per. F. uneven
n	Fe-blk. to gry. & brnh-blk.	Res. to submet.	6	5.3–6.5	5–5.5	Orth.; us. prism.	F. uneven
s)	Velvet-blk.	Vitreous to res.	5–6	5.6–5.8	4.5–5	Orth.; us. mass.	F. conch.
	Dk. gryh-blk. to brnh. blk.	Res. to submet.	5–5.5	7.2–7.5	3–3.5	Mon.; us. xls.	C. pinac. per. F. uneven
	Brn. to brnh-blk.	Res.	5–5.5	6.89–7.35	4	Mon.	C. pinac. per. F. uneven
u)	Wh., yel., grn., brn., redh.	Vitr. to adamant	4.5–5	5.9–6.1	5	Tetr.	C. pyram. F. uneven
)	Gry., brn., yel., grn.	Res. to adamant	5–5.5	3.4–3.56	3	Mon.; us. xls.	C. prism. F. uneven
	Sapphire-blue, lt. blue, cols.		6.25–6.5	3.64–3.65	3	Hex.; us. prism.	

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SECTION 23—*Continued*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

5. Insoluble in HCl or nearly so.

		Name.	Composition.
GARNET. — Fus. quietly (except uvarovite) and gel. w. HCl after fus. Us. dodecahedrons and trapezohedrons. (Figs. 13, 17, 18)	Ca (grossularite) or Mg (pyrope) ppt. after fus. w. soda and separating Si and Al. (See Silicon (2))	**GROSSULARITE** (Ca-Al Garnet) T416 S439	$Ca_3Al_2(SiO_4)_3$ (Fe, Mg, Mn iso. w. (Fe iso. w. Al)
		PYROPE (Mg-Al Garnet) T416 S440	$Mg_3Al_2(SiO_4)_3$ (Fe, Ca iso. w. Mg; Fe, Cr, iso. w. Al)
	Fus. to mag. globule	**ALMANDITE** (Fe-Al Garnet) T416 S441	$Fe_3Al_2(SiO_4)_3$ (Mn, Mg, Ca iso. w.
	Mn in borax bd. (strong)	**SPESSARTITE** (Mn Garnet) T417 S442	$Mn_3Al_2(SiO_4)_3$ (Fe, Ca iso. w. Mn; Fe iso. w. Al)
	Partially sol. in HCl w. gel. sil.	**ANDRADITE** (Ca-Fe Garnet) T417 S437	$Ca_3Fe_2(SiO_4)_3$ (Fe, Mn, Mg, Ca iso. Ca; Al iso. w. Fe)
	Cr in s.ph. bd.; fus. w. dif.	**Uvarovite** (Ca-Cr Garnet) T417 S444	$Ca_3Cr_2(SiO_4)_3$ (Al iso. w. Cr)
AMPHIBOLE Group.—Fus. quietly or w. little intumes. Prism and cl. angles 56° and 124°. Xls. us. prismatic, often divergent or radial-columnar. Separate xls. us. 6-sided, vertically striated, and terminated by 2 planes	Fus. to dark shiny globule; us. intumes. slightly and gives Na flame	**HORNBLENDE AMPHIBOLE** T402 S392	$Ca(Mg,Fe)_3(SiO_3)$ $Na_2(Al,Fe)_2(SiO_3$ $(Mg,Fe)_2(Al,Fe)$ $(SiO_6)_2$
	Fus. to grnh. or brnh. globule; but little Na flame	**ACTINOLITE** (Nephrite or Jade when compact) T400 S389	$Ca(Mg,Fe)_3(SiO_3)$
	Fus. to cols. or nearly cols. glass; sometimes asbestiform (fibrous)	**TREMOLITE** (Asbestos in part) T400 S388	$CaMg_3(SiO_3)_4$
	Dif. fus. (5–6); sometimes asbestiform	**Anthophyllite** (Asbestos in part) T398 S384	$(Mg,Fe)SiO_3$ (Somet. also Al)
	Strong Na flame (Cp. riebeckite)	**Glaucophane** T403 S399	$Na_2Al_2(SiO_3)_4.$ $(Mg,Ca,Fe)SiO_3$
PYROXENE Group. —Fus. quietly or w. little intumes. Prism and cleav. angles 87° and 93°; cleav. not very pronounced. Xls. us. nearly square prism w. truncated edges. Basal parting often distinct	Dif. fus. (6); luster often metaloidal (Cp. hypersthene)	**ENSTATITE** (Bronzite) T384 S346	$(Mg,Fe)SiO_3$
	Fus. to cols. or nearly cols. glass	**DIOPSIDE** T388 S355	$CaMg(SiO_3)_2$ (Fe iso. w. Mg)
	Fus. to grnh. or brnh. glass; col. deepens w. increase of Fe. Diallage is lamellar to fibrous w. pearly to metalloidal luster	**PYROXENE** (Diallage) T387 S356	$Ca(Mg,Fe)(SiO_3)_2$
	(Continued next page)	**Hedenbergite** T389 S352	$CaFe(SiO_3)_2$ (Mg iso. w. Fe)

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
a;	Pale red, yel., grn., wh.	Vitreous	6.5–7.5	3.55–3.66	3	Iso.: us. xls.	F. uneven to conch
	Deep red to redh-blk., rarely purple	Vitreous	6.5–7.5	3.7–3.75	3.5–4	Iso.; us. xls.	F. uneven to conch.
e)	Deep red to brnh-blk.	Vitreous	6.5–7.5	3.9–4.2	3	Iso.; us. xls.	F. uneven, conch.
	Brnh-red to hyacinth-red	Vitreous	6.5–7.5	4.0–4.3	3	Iso.; us. xls.	F. uneven to conch.
w.	Wine-red, grnh., yel., brn. to blk.	Vitr. to res.	6.5–7.5	3.8–3.9	3.5	Iso.; us. xls.	F. uneven to conch.
	Emerald-grn.	Vitreous	7.5	3.41–3.52	5.5–6	Iso.; us. xls.	F. conch.
. '4.	Grn. to blk.	Vitr. to pearly	5–6	3.05–3.47	3–4	Mon.; us. xls.	C. prism. per. F. uneven
	Grn. of various shades	Vitr. to pearly	5–6	3.0–3.2	4	Mon.; prism.	C. prism. per. F. uneven
	Wh., gry.	Vitr. to pearly	5–6	2.9–3.1	4	Mon.	C. prism. per. F. uneven
	Gry., clove-brn., grn.	Vitr. to pearly	5.5–6	3.1–3.2	5–6	Orth.; us. fibr. or mass.	C. prism. per.
	Lavender-blue to azure-blue; gryh., and bluish-blk.	Vitr. to pearly	6–6.5	3.10–3.11	3–3.5	Mon.; us. mass.	C. prism. per. F. uneven
	Yelh., gry., brn., grn.	Pearly to bronzy	5.5	3.1–3.3	5–6	Orth.; us. mass.	C. prism. F. uneven
	Cols., wh., pale grn.	Vitreous	5–6	3.2–3.38	4	Mon.; us. xls.	C. prism. F. uneven
	Lt. to dk. grn.	Vitreous	5–6	3.1–3.5 Us. 3.3	4	Mon.; us. xls. Figs. 62, 63	C. prism. F. uneven
	Grnh-blk. to blk.	Vitreous	5–6	3.5–3.58	2.5–3	Mon.	C. prism. F. uneven

SECTION 23—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

5. Insoluble in HCl or nearly so.

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SECTION 23—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.

Part III. Does not give a metal globule with powdered charcoal and soda nor become magnetic on heating in the reducing flame.

5. Insoluble in HCl or nearly so.

			Name.	Composition.
	Fus. to shiny blk. glass; often Na flame; contains Al and ferric Fe		**AUGITE** (Common Pyroxene of igneous rocks) T390 S358	$Ca(Mg,Fe)(SiO_3)_2$ $(Mg,Fe)(Al,Fe)_2S$ $Na(Al,Fe)(SiO_3)_2$
	Fus. to blk. globule, somewhat mag.; strong Na flame		**Acmite** (Aegirite) T391 S364	$NaFe'''(SiO_3)_2$
	Fus. readily to transp. blebby glass; Na flame. Us. in very tough compact mass		**Jadeite** (Jade in part) T393 S369	$NaAl(SiO_3)_2$
Fus. easily to wh. transl. glass	Wh. ppt. $BaSO_4$ in HCl sol.; much H_2O in c.t. at low temp.		**Harmotome** T456 S581	$H_2(Ba,K_2)Al_2(SiC$ $4H_2O$
Fus. easily to cols. blebby glass	Sol. w. gel. after ign.; H_2O in c.t.; very hard		Lawsonite T447 Ap. I, 41	$Ca[Al(OH)_2]_2(SiO$
Fus. dif. and quietly (Cp. sericite, variety of muscovite)	Whitens and fus. to vesic. scoria; varieties with Na, Li, Cs, more fus.		**BERYL** (Emerald, deep grn.; Aquamarine, pale) T405 S405	$H_2Gl_6Al_4Si_{12}O_{37}$ (Na_2, Li_2, Cs_2 iso. w.
	A little H_2O on intense ign. of powder in c.t.		**Iolite** (Cordierite) T407 S419	$H_2(Mg,Fe)_4$ $Al_8Si_{10}O_{37}$
Fus. to wh. enamel w. orange-yel. phosphorescence	Acid H_2O in c.t.; P reac. w. am. mol. after fus. w. soda		Herderite T503 S760	$Ca[Gl(F,OH)]PO$
Fus. w. intumes.	To grnh. or brnh. glass; gel. w. HCl after fus.		**VESUVIANITE** (Idocrase) T427 S477	$Ca_6[Al(OH,F)]$ $(Al,Fe)_2(SiO_4$ (Mg, Fe, Mn iso. w.
	To wh. blebby glass; strong Na flame; AgCl ppt. w. $AgNO_3$ in dil. HNO_3 sol. after fus. w. soda		**WERNERITE** (Scapolite) T425 S468	$n(Ca_4Al_6Si_6O_{25})$ $m(Na_4Al_3Si_9O_{24}Cl$ ($n : m = 3 : 1$ to $1 : 2$
	To wh. blebby glass; gel. w. HCl after fus. H_2O in c.t.		**PREHNITE** T442 S530	$H_2Ca_2Al_2(SiO_4)_3$ (Fe iso. w. Al)
	To a slag which gel. w. HCl; a little H_2O on intense ign. of powder in c.t.	Lt. col. slag	**ZOISITE** T437 S513	$Ca_2(AlOH)Al_2(Si$
		Brn. or blk. slag; us. mag.	**EPIDOTE** (Pistacite) T438 S516	$Ca_2(AlOH)(Al,Fe$ $(SiO_4)_3$
Exfoliates and fus. w. dif. Greasy feel	Pink col. after ign. w. $Co(NO_3)_2$; us. gives H_2O in c.t. on intense ign.		**TALC** (Steatite, Soapstone) T479 S678	$H_2Mg_3(SiO_3)_4$

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
O_6	Grnh-blk. to blk.	Vitreous	5–6	3.26–3.43	3–4	Mon.	C. prism. F. uneven
	Grnh. to brnh-blk.	Vitreous	6–6.5	3.50–3.55	3.5	Mon.; prism.	C. prism. F. uneven
	Wh., gryh., grnh.	Vitreous C. pearly	6.5–7	3.33–3.35	2.5	Mon.; us. mass.	C. prism. F. splint.
$)_5$.	Wh., gry., yel., red, brn.	Vitreous	4.5	2.44–2.50	3.5	Mon.; us. twinned	C. pinac. F. uneven
$)_2$	Pale blue to gryh-blue	Vitr. to greasy	8.25	3.084–3.091	3	Orth.; us. xls.	C. basal and pinac., per.
31)	Grn., blue, yel., pink, cols.	Vitr. to res.	7.5–8	2.63–2.80 Us. 2.69–2.7	5–5.5	Hex.; us. xls.	F. conch. to uneven
	Blue to violet and cols.	Vitreous	7–7.5	2.60–2.66	5–5.5	Orth.	C. pinac. F. conch.
	Wh. to pale grn. or yel.	Vitreous	5	2.99–3.01	4–5	Mon.	F. uneven
Ca)	Grn., brn., yel., blue, red	Vitr. to res.	6.5	3.35–3.45	3	Tetr. Figs. 37, 38	F. uneven
)	Wh., gry., grnh., bluish, redh.	Vitr. to pearly	5–6	2.66–2.73	3	Tetr.	C. prism. and pinac. F. uneven
	Apple-grn., gry., wh.	Vitreous	6.6–5	2.80–2.95	2	Orth.; us. reniform	F. uneven
$)_4)_2$	Gryh-wh., grn., pink, yelh-brn.	Vitreous; C. pearly	6–6.5	3.25–3.37	3–4	Orth.; us. prism.	C. pinac. per. F. uneven
$)_2$	Yelh. to blkh-grn., gry.	Vitreous	6–7	3.25–3.5	3–4	Mon.; us. prism.	C. basal, per. F. uneven
	Apple-grn., gry., wh.	Greasy; C. pearly	1–2.5	2.55–2.80	5	Mon.; us. fol. or mass.	C. basal, per.

SECTION 24

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

1. Alkaline reaction on moist turmeric paper after intense ignition.

			Name.	Compositi
CARBONATES.—CO_2 efferv. in dil. HCl	Sr flame; swells and throws out fine branches on intense ign.	Wh. ppt. $SrSO_4$ w. dil. H_2SO_4 in dil. HCl sol.	**STRONTIANITE** T362 S285	$SrCO_3$ (Somet. Ca iso w.
	Ba flame on intense ign.	Wh. ppt. $BaSO_4$ w. dil. H_2SO_4 in dil. HCl sol.	Barytocalcite T364 S289	$CaBa(CO_3)_2$
	Ca flame w. HCl; dil. H_2SO_4 gives wh. ppt. $CaSO_4$ in conc. HCl sol. but not in very dil. sol., showing presence of Ca and absence of Sr and Ba	Lumps efferv. freely in cold dil. HCl. Aragonite powder colored lavender on boiling in $Co(NO_3)_2$ sol. (See p. 25)	**CALCITE** (Calc Spar; Marble; Limestone; Chalk.) T354 S262	$CaCO_3$ (Mg, Fe, Mn, Pb i
			ARAGONITE T361 S281	$CaCO_3$ (Sr, Pb iso. w. Ca
		Lumps efferv. freely in hot but not in cold dil. HCl; sol. reac. for Mg after ppt. of Ca	**DOLOMITE** (Pearl Spar) T357 S271	$CaMg(CO_3)_2$ (Fe, Mn, iso. w. M
		Becomes blk. and slightly mag. on ign.; much $Fe(OH)_3$ ppt. w. am. after boiling HCl sol. w. a drop of HNO_3	**Ankerite** (Fe Dolomite) T358 S274	$Ca(Mg,Fe)(CO_3$ (Mn iso. w. Mg)
		Much H_2O in c.t.; wh. $BaSO_4$ ppt. w. $BaCl_2$ in dil. HCl sol.	Thaumasite T483 S698	$CaCO_3.CaSiO_3.($ $15H_2O$
	Contains Mg.—Little or no ppt. w. am. oxalate in HCl sol., but much w. Na phosphate Alkaline reac. w. turmeric paper may be weak	Scarcely affected by cold dil. HCl. Wh. fragments become pale pink on ign. w. $Co(NO_3)_2$. Breunnerite gives much $Fe(OH)_3$ ppt. w. am. after boiling HCl sol. w. a drop of HNO_3. Hydromagnesite gives much H_2O in c.t.	**MAGNESITE** T358 S274	$MgCO_3$ (Fe iso. w. Mg)
			Breunnerite (Fe Magnesite; Brown Spar) T358 S274	$(Mg,Fe)CO_3$ (Mn iso. w. Mg)
			Hydromagnesite T367 S304	$Mg_3(MgOH)_2(C$
Sol. quietly in warm HCl	Glows on ign.; becomes pale pink if previously moistened w. $Co(NO_3)_2$		**BRUCITE** T351 S252	$Mg(OH)_2$ (Fe, Mn iso. w. Mg
Sulphates.—Acid H_2O in c.t. and SO_2 odor after intense ign.	Al reac. w. $Co(NO_3)_2$	Readily sol. in H_2O	**Kalinite** (Potash Alum) T535 S951	$KAl(SO_4)_2.12H$
		Slowly attacked by HCl	**Alunite** T537 S974	$K[Al(OH)_2]_3(SO_4$ (Na iso. w. K)

	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Wh., gry., yel., grn.	Vitreous	3.5–4	3.68–3.71	Orth.; us. columnar	C. prism. F. uneven
	Wh., gry., yel., grn.	Vitreous	4	3.64–3.66	Mon.; us. prism.	C. prism. per. F. uneven
. w. Ca)	Cols., wh., and variously tinted	Vitreous	3	2.71–2.72	Hex.; rhom. Figs. 45–50	C. rhom. per. F. conch.
	Cols., wh., and variously tinted	Vitreous	3.5–4	2.93–2.95	Orth.	C. pianc. poor F. uneven
	Cols., wh., and variously tinted	Vitr. to pearly	3.5–4	2.8–2.9	Hex. rhom.	C. rhom. per.
	Brn., gry., redh., seldom wh.	Vitr. to pearly	3.5–4	2.95–3.1	Hex. rhom.	C. rhom. per.
aSO$_4$.	Wh., cols.	Vitr. to dull	3.5	1.877	Hex.; fibr. or mass.	F. splint.
	Wh., yel., gry., brn.	Vitreous, silky, dull	3.5–4.5	3.0–3.12	Hex. rhom.; us. mass.	C. rhom. per.
	Yelh., brnh., gry. Seldom wh.	Vitreous	3.5–4.5	3.0–3.2	Hex. rhom.	C. rhom. per.
)$_2$.3H$_2$O	Wh.	Vitr. to silky	3.5	2.15	Mon.; us. acic.	
	Wh., gry., grn., blue	Waxy, vitr. C. pearly	2.5	2.38–2.4	Hex. rhom.; us. tab.	C. basal, per.; flex.
	Cols., wh.	Vitreous	2–2.5	1.75	Iso. pyr.; us. fibr.	C. conch.
	Wh., gry., redh.	Vitreous	3.5–4	2.58–2.75	Hex. rhom.	C. basal F. uneven

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SECTION 25

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

2. Soluble in HCl without residue or the formation of gelatinous silica upon evaporation.

			Name.	Compositio
CARBONATES.—CO_2 efferv. in dil HCl.	Mn in borax bd.	Sometimes enough Fe to make mag. on ch.	**RHODOCHROSITE** (Dialogite) T359 S278	$MnCO_3$ (Ca, Fe, Mg, Zn iso.
	Ni in borax bd.	H_2O in c.t.	**Zaratite** T367 S306	$(NiOH)_2CO_3.Ni($ $4H_2O$
	Wh. ZnO subl. w. soda on ch. Grn. subl. if ch. previously moistened w. $Co(NO_3)_2$	Little or no H_2O in c.t.	**SMITHSONITE** (Dry-bone Ore; Calamine) T360 S279	$ZnCO_3$ (Ca, Mg, Fe, Mn, C
		H_2O in c.t.; Cu flame w. HCl	**Aurichalcite** T366 S298	$2(Zn,Cu)CO_3.3(Z$ $(OH)_2$
		H_2O in c.t.; no Cu	Hydrozincite T366 S299	$ZnCO_3.2Zn(OH)_2$
	Become blk. and mag. on ign.; ferrous Fe	HCl sol. reac. for both Mg and Fe. (See breunnerite, Sec. 24)	**Breunnerite** (Fe Magnesite; Brown Spar) T358 S274	$(Mg,Fe)CO_3$ (Mn iso. w. Mg)
		Little or no Mg or Ca. (See Magnesium (3))	**SIDERITE** (Spathic Iron) T359 S276	$FeCO_3$ (Ca, Mg, Mn iso. w.
	Mg reac. in HCl. sol. after removing Fe and Ca. (See Magnesium (3))	Little or no H_2O in c.t.	**MAGNESITE** T358 S274	Mg CO_3 (Fe iso. w. Mg)
		Much H_2O in c.t.	Hydromagnesite T367 S304	$Mg_2(MgOH)_2(CC$
SULPHIDES.—H_2S efferv. in hot HCl	Wh. ZnO subl. after intense ign. w. soda on ch.; subl. grn. w. $Co(NO_3)_2$		**SPHALERITE** (Zinc Blende) T291 S59	ZnS (Fe, Mn, Cd iso. w.
	Red-brn. CdO subl. after intense ign. w. soda on ch.		**Greenockite** T294 S69	CdS
SULPHATES.—Wh. ppt. $BaSO_4$ w. $BaCl_2$ in HCl sol.	Al reac. w. $Co(NO_3)_2$ on ch.	Readily sol. in H_2O; K flame	**Kalinite** (Potash Alum) T535 S951	$KAl(SO_4)_2.12H_2C$
		Sol. in H_2O; no flame reac.	Alunogen T535 S958	$Al_2(SO_4)_3.18H_2O$
		Insol. in H_2O	Aluminite T537 S970	$Al_2(OH)_4SO_4.7H_2$
	Readily sol. in H_2O; wh. ZnO subl. w. soda on ch. after intense ign.		Goslarite T533 S939	$ZnSO_4.7H_2O$ (Fe iso. w. Zn)

...	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
w. Mn)	Rose-red, dk. red, brn.	Vitr. to pearly	3.5–4.5	3.45–3.60	Hex. rhom.; us. mass.	C. rhom. per. F. uneven
H)₂.	Emerald-grn.	Vitreous	3–3.25	2.6–2.7	Mass.; compact	F. smooth
iso. w. Zn)	Brn., grn., blue, pink, wh.	Vitreous	5	4.30–4.45	Hex. rhom.; us. botry.	C. rhom. per. F. uneven
,Cu)	Pale grn. to blue	Pearly	2	3.54–3.64	Mon.; us. acic.	
	Wh., gry., yel.	Dull	2–2.5	3.58–3.8	Earthy; compact	
	Yelh. brnh., gry. Seldom wh.	Vitreous	3.5–4.5	3.0–3.2	Hex. rhom.	C. rhom. per.
Fe)	Gry. & brn. of different shades	Vitr. to pearly	3.5–4	3.83–3.88	Hex. rhom.	C. rhom. per. F. uneven
	Wh., yel., gry., brn.	Vitreous, silky, dull	3.5–4.5	3.0–3.12	Hex. rhom.; us. mass.	C. rhom. per.
)₂.3H₂O	Wh.	Vitreous to silky	3.5	2.15	Mon.; us. acic.	
n)	Wh., grn., yel., red, brn., blk.	Res. to adamant	3.5–4	3.9–4.1	Iso. tetr.; us. mass.	C. dodec. per. F. conch.
	Honey, citron, or orange-yel.	Res. to adamant	3.0–3.5	4.9–5.0	Hex. hemimor.; us. incrust.	C. prism. F. conch.
	Cols., wh.	Vitreous	2–2.5	1.75	Iso. pyr.; us. fibr.	C. conch.
	Wh., yelh., redh.	Vitr. to silky	1.5–2	1.6–1.8	Mon.; us. fibr.	
)	Wh., opaq.	Dull, earthy	1–2	1.66	Mon.; us. compact, reniform	F. earthy
	Wh., yelh., redh.	Vitreous	2–2.5	1.9–2.1	Orth.; us. mass.	C. pinac. per.

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SECTION 25—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

2. Soluble in HCl without residue or the formation of gelatinous silica upon evaporation.

SECTION 26

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

3. Soluble in HCl with the formation of gelatinous silica upon evaporation.

			Name.	Compositi
Contains Fe; blackens and becomes strongly mag. b.b.; fus. (5–6) in fine splinters; slowly sol. in HCl to yel. sol. which reacts for ferric Fe	St. brnh-red	Little or no H_2O in c.t.	**HEMATITE** T334 S213	Fe_2O_3
		H_2O in c.t.; us. decrepitates	**Turgite** (Hydrohematite) T350 S245	$(FeO.OH)_2Fe_2O_3$
	St. yelh-brn. H_2O in c.t.	Us. prismatic xls.	**GOETHITE** (Göthite) T349 S247	$FeO(OH)$
		Amorphous, mammillary, botryoidal, stalactitic	**LIMONITE** (Brown Hematite; Bog Iron Ore) T350 S250	$Fe_2(OH)_6Fe_2O_3$
Mn in borax bd.	Wh. ZnO subl. w. soda on ch. after intense ign.; subl. grn. w. $Co(NO_3)_2$		**ZINCITE** (Red Zinc Ore) T332 S208	ZnO (Mn iso. w. Zn)
	Earthy, powdery, frothy; H_2O in c.t.		**WAD** (Bog Manganese) T352 S257	MnO,MnO_2,H_2O (Often Fe, Si, Al, B
Co in borax bd.	Mn in soda bd.; H_2O in c.t.		Asbolite (Earthy Cobalt) T352 S258	Co,Mn oxides (Often Fe, Si, Al)
P reac. w. am. mol.	Cu flame		**Turquois** T512 S844	$H[Al(OH)_2]_2PO_4$ (CuOH iso. w. Al(
	Wh. $CaSO_4$ ppt. w. H_2SO_4 in cold conc. HCl sol. F reac. w. H_2SO_4		**APATITE** T497 S762	$Ca_4(CaF)(PO_4)_3$ (Cl iso. w. F. Rare
Much Mg; no Ca. See Magnesium (3)	Brilliant glow on intense ign.; Mg reac. w. $Co(NO_3)_2$ on ch. if mineral is lt. col.		**BRUCITE** T351 S252	$Mg(OH)_2$ (Fe, Mn iso. w. M

SEC. 26. Nonmetallic luster; st. light; fus

Wh. ZnO subl. w. soda on ch. Grn. subl. if ch. previously moistened w. $Co(NO_3)_2$.	H_2O in c.t.; pyroelectric		**CALAMINE** (Hemimorphite; Smithsonite) T446 S546	$(ZnOH)_2SiO_3$
	Little or no H_2O in c.t.	A little H_2S on sol. in HCl	Danalite T414 S435	$Gl_3R_3(RS)(SiO_4)_3$ (R = Mn, Fe, Zn)
		No H_2S on sol. in HCl (Cp. troostite)	**WILLEMITE** T422 S460	Zn_2SiO_4 (Mn, Fe iso. w. Zn)
Cu globule w. soda on ch.	H_2O in c.t.		**Dioptase** T424 S463	H_2CuSiO_4

l.	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Red to redh-blk.	Dull to submet.	5.5–6.5	4.9–5.3	Mass.; earthy	F. uneven, splint.
	Red to redh-blk.	Dull to submet.	5.5–6	4.14–4.6	Botry.; crusts	F. uneven, splint.
	Yel. or redh-brn. to blk.	Dull to adamant.	5–5.5	4–4.4	Orth.; us. prism.	C. pinac. per. F. splint.
	Yel., brn. to brnh. blk.	Dull, silky	5–5.5	3.6–4	Mass.; fibr.	F. splint
	Deep red to orange-yel. St. yel.	Adamant.	4–4.5	5.43–5.7	Hex. hemimor.; us. mass.	C. basal, per. F. uneven
	Bluish or brnh-blk. to dull blk.	Dull	1–6	3–4.26	Earthy; mass.	F. uneven
	Blk., brn.	Dull	1–2.5	3.15–3.29	Mass.; earthy	
D₂)	Blue, bluish-grn., grn.	Waxy	6	2.6–2.8	Tri.; us. mass.	F. uneven to conch.
Mn)	Grn., blue, violet, brn., yelh., cols.	Vitr. to subres.	4.5–5	3.17–3.23	Hex.	C. basal, F. uneven.
	Wh., gry., grn., blue	Waxy, vitr.; C. pearly	2.5	2.38–2.4	Hex. rhom.; us. tab.	C. basal, per.; flex.

above 5; not alk. after ign.; sol. in HCl w. gel. sil.

	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Wh., pale-grn., blue	Vitreous	4.5–5	3.4–3.5	Orth. hemimor.	C. prism. per. F. uneven
	Flesh-red to gry.	Vitr. to res.	5.5–6	3.427	Iso tetrh.; us. mass.	F. uneven
	Yel., red, grn., brn., wh., cols.	Vitreous	5.5	3.9–4.18	Hex. rhom.	C. basal and prism. F. uneven
	Emerald-grn.	Vitreous	5	3.28–3.35	Hex. rhom.; us. prism.	C. rhom. per. F. conch.

SECTION 26—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

3. Soluble in HCl with the formation of gelatinous silica upon evaporation.

SECTION 27

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

4. Decomposed by HCl with separation of silica, but without complete solution or the formation of jelly.

		Name.	Compositi
Fe in borax bd.; little or no H_2O in c.t. (Cp. the next 3 minerals, which often react for Fe)	Much Mg but no Al or Ca in HCl sol. (See Magnesium (3))	**CHRYSOLITE** (Olivine, Peridot) T420 S451	$(Mg,Fe)_2SiO_4$
	Swells and cracks apart on ign.; often glows	**Gadolinite** T436 S509	$Gl_2Fe(YO)_2(SiO_4)$
F reac. w. $KHSO_4$ and glass in c.t.; may also react for Fe	A little H_2O on intense ign. in c.t.; disting. by xln. or by quantitative chemical analysis	**Chrondrodite** T443 S536	$Mg_3[Mg(F,OH)]_2$
		Humite T443 S 535	$Mg_5[Mg(F,OH)]_2$
		Clinohumite T443 S538	$Mg_7[Mg(F,OH)]_2$
Al reac. w. $Co(NO_3)_2$ on ch.	Much H_2O in c.t.; crumbles on ign.	**Allophane** T483 S693	$Al_2SiO_5.5H_2O$

SEC. 27. Nonmetallic luster; st. light; fus. above 5; n

Cu globule w. soda on ch.	Darkens and gives H_2O in c.t.	**Chrysocolla** T483 S699	$CuSiO_3.2H_2O$
Ni in borax bd.	Darkens and gives H_2O in c.t.	**Garnierite** (Genthite) T479 S676	$H_2(Ni,Mg)SiO_4.$
Blackens and becomes mag. b.b.	H_2O in c.t.; ferric Fe in HCl sol.	Chloropal T484 S701	$H_6Fe_2(SiO_4)_3.2H$
H_2O in c.t.; amorphous, fibrous, or foliated	Us. compact grnh.; sometimes fibrous (chrysotile, commercial "asbestos") or foliated (marmolite)	**SERPENTINE** (Chrysotile; Marmolite) T476 S669	$H_4(Mg,Fe)_3Si_2O_9$ (Somet. Ni, iso. w.
	Resembles a gum or resin	**Deweylite** (Gymnite) T479 S676	$H_4Mg_4(SiO_4)_3.2H$ (Somet. Ni iso. w.
	Compact; fine earthy texture; Mg reac. w. $Co(NO_3)_2$ on ch. Fus. = 5. Adheres to tongue	Sepiolite (Meerschaum) T480 S680	$H_4Mg_2Si_3O_{10}$ (Somet. Cu and Ni
Al reac. w. $Co(NO_3)_2$ on ch.	K flame w. powdered gypsum; us. trapezohedrons	**LEUCITE** T381 S342	$KAl(SiO_3)_2$ (Na iso. w. K)
	Clay-like; sometimes transl. or transp. in H_2O	Halloysite T481 S688	$H_4Al_2Si_2O_9.nH_2O$

. above 5; not alk. after ign.; sol. in HCl w. gel. sil.

n.	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Olive-grn. to gryh-grn., brn.	Vitreous	6.5–7	3.27–3.37	Orth. Fig. 58	C. pinac. F. conch.
	Blk., grnh.-blk., brn.	Vitr. to greasy	6.5–7	4.0–4.5	Mon.; us. mass.	F. conch., splint.
$(SiO_4)_2$	Brnh-red., yel., wh.	Vitreous	6–6.5	3.1–3.2	Mon.	C. basal F. uneven
$(SiO_4)_3$	Brnh-red, yel., wh.	Vitreous	6–6.5	3.1–3.2	Orth.	C. basal F. uneven
$(SiO_4)_4$	Brnh-red., yel., wh.	Vitreous	6–6.5	3.1–3.2	Mon.	C. basal F. uneven
	Cols., yel., grn., blue	Vitr. to waxy	3	1.85–1.89	Amorph.; us. crusts	F. conch.

t alk. after ign.; decomposed by HCl w. separation of sil.

	Bluish-grn., grnh-blue, brn., blk.	Vitreous, earthy	2–4	2.0–2.24	Mass.; earthy	F. conch. to uneven
H_2O	Pale to deep grn., yelh.	Dull to res.	1–4	2.2–2.8	Amorph.; botry.	F. uneven
O	Grnh. yel., pistachio-grn.	Waxy	2.5–4.5	1.73–1.87	Compact; amorph.	F. conch., splint., earthy
Mg)	Olive-grn., blkh-grn., yelh-grn.,wh.	Greasy, waxy, silky	2.5–5 Us. 4	2.5–2.65	Mass.; pseudm.	F. uneven, splint.
$_2O$ (g)	Yelh-brn., wh., apple-grn.	Res.	2–3.5	2.0–2.2	Amorph.	F. uneven, conch.
so. w. Mg)	Wh., to gryh-wh.	Dull	2–2.5	2.0	Compact; earthy	F. uneven
	Wh., gry., cols.	Vitreous	5.5–6	2.45–2[illegible]	Iso.; us. xls.	F. uneven, conch.
	Wh., gry., grnh., yelh., bluish, redh.	Pearly, waxy, dull	1–2	2.0–[illegible]	Mass.; earthy	

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SECTION 28

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

5. Insoluble in HCl or nearly so.

a. Can be scratched with a knife; will not scratch glass.

			Name.	Compositi
Wh. ZnO subl. w. soda on ch.; grn. w. $Co(NO_3)_2$		Slowly attacked by hot HCl w. evolution of H_2S	**SPHALERITE** (Zinc Blende) T291 S59	ZnS (Fe, Mn, Cd iso. w.
Become strongly mag. on ign.		Slowly and dif. sol. in HCl	**IRON ORES** See Section 13	
Micaceous or foliated	Foliæ tough and elastic	Fus. w. dif.	**MICAS** See Section 23	
	Foliæ flexible but not elastic (Cp. talc, below)	Much H_2O in c.t. on intense ign.; varieties rich in Fe become black and mag. (prochlorite)	**CHLORITE** (Clinochlore; Penninite; Prochlorite) T472 S643	$H_8(Mg,Fe)_5Al_2Si_3$ (Often a little Cr)
		Cr in borax bd.; rdh. col.	**Kämmererite** (Chrome Chlorite) T474 S650	$H_8(Mg,Fe)_5(Al,C$
	Foliæ brittle (brittle micas) H_2O in c.t.	Whitens and fus. w. dif. on thin edges	**Margarite** (Brittle Mica) T470 S636	$H_2CaAl_4Si_2O_{12}$
		Whitens b.b., but infus.	**Seybertite** (Clintonite) T471 S638	$H_3(Mg,Ca)_5Al_5Si_2$
Greasy feel; very soft	A little H_2O in c.t. on intense ign. (Cp. kaolinite and bauxite, below)	Al reac. w. $Co(NO_3)_2$ on ch.; radiated variety exfoliates greatly b.b.	**PYROPHYLLITE** (Agalmatolite) T482 S691	$H_2Al_2(SiO_3)_4$
		Mg reac. w. $Co(NO_3)_2$ on ch.	**TALC** (Steatite; Soapstone) T479 S678	$H_2Mg_3(SiO_3)_4$
	Much H_2O readily given in c.t.	Like butter or cheese; brittle when dry; decomposed by H_2SO_4	Saponite T480 S682	$Mg_4Al(OH)_2(SiO_3$
P reac. w. am. mol. after fus. w. soda; us. pale blue-grn. flame		Monazite us. transp. or transl.; Xenotime is opaq.	**MONAZITE** T495 S749	(Ce,La,Nd,Pr)PO (Often w. $ThSiO_4$)
			Xenotime T494 S748	YPO_4 (Er; somet. Ce and
		Al reac. w. $Co(NO_3)_2$ on ch.; wavellite us. radiated or globular; variscite sheaf-like and reniform	**Wavellite** T512 S842	$(AlOH)_6(PO_4)_4.9$ (F iso. w. OH)
			Variscite T510 S824	$AlPO_4.2H_2O$
		Blue col.; b.b. swells, loses col. and crumbles	**Lazulite** T506 S798	$(Mg,Fe)(AlOH)_2($

.	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
1)	Wh.,grn., yel., red, brn., blk.	Res. to adamant	3.5–4	3.9–4.1	Iso. tetrh.; us. mass.	C. dodec. per. F. conch.
$_{18}$	Grn. of various shades	Vitr. to pearly	1–2.5	2.6–2.96	Mon.	C. basal, per.
$_3Si_3O_{18}$	Rose-red to deep red	Vitr. to pearly	2–2.5	2.65–3.1	Mon.	C. basal, per.
	Pink, gry., wh., yelh.	Vitreous; C. pearly	3.5–4.5	2.99–3.08	Mon.	C. basal, per.; brittle
$_{18}$	Redh-brn., Cu-red, yelh.	Pearly to submet.	4–5	3.0–3.1	Mon.	C. basal, per. F. uneven
	Wh., apple-grn., gry., yel., brn.	Pearly to dull	1–2	2.8–2.9	Fol., fibr., mass.	C. basal, per.; flexible
	Apple-grn., gry., wh.	Greasy; C. pearly	1–2.5	2.55–2.80	Mon. us.; fol. or mass.	C. basal, per.
$_3.14H_2O$	Wh., yelh., grnh., bluish, redh.	Greasy		2.24–2.30	Amorph.; mass.	
	Yelh-grn. to yelh- and redh-brn.	Res.	5–5.5	4.9–5.3	Mon.	P. (?) basal F. uneven
h)	Yelh. to redh-brn.	Res. to vitr.	4–5	4.45–4.56	Tetr.	C. prism. per. F. uneven
$_2O$	Wh., yel., grn., brn.	Vitr. to pearly	3–4	2.32–2.34	Orth.; us. radial	C. pinac. F. uneven
	Cols., apple-grn. to emerald-grn.	Vitreous	4	2.4	Orth.; us. mass.	
$O_4)_2$	Azure-blue	Vitreous	5–6	3.05–3.12	Mon.	C. prism. F. uneven

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SECTION 28—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

5. Insoluble in HCl or nearly so.

a. Can be scratched with a knife; will not scratch glass.

SECTION 29

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

5. Insoluble in HCl or nearly so.

b. Cannot be scratched with a knife; will scratch glass.

			Name.	Compositio
Al reac. w. $Co(NO_3)_2$ on ch.	Little or no H_2O in c.t.		**CYANITE** (Disthene) T434 S500	$(AlO)_2SiO_3$
	H_2O in c.t.	SO_2 fumes and acid H_2O w. intense heat in c.t.	**Alunite** T537 S974	$K[Al(OH)_2]_3(SO_4)_2$ (Na iso. w. K)
		Insol. sil. skeleton in s.ph.bd.; us. clay-like, compact, or mealy	**KAOLINITE** (Kaolin; Porcelain Clay) T481 S685	$H_4Al_2Si_2O_9$
		Wholly sol. in s.ph. bd. Gibbsite us. incrust. or stalactitic; bauxite pisolitic and clay-like	**BAUXITE** (Aluminum Ore) T350 S251	$Al_2O(OH)_4$ (Often Fe, Si, Ca, M
			Gibbsite (Hydrargillite) T351 S254	$Al(OH)_3$
Ni in borax bd.	Blackens and gives H_2O in c.t.		**Garnierite** (Genthite) T479 S676	$H_2(Ni,Mg)SiO_4.n$
W in s.ph. bd.; yel. WO_3 res. in boiling HCl	Ca reac. w. am. oxalate in HCl sol.		**Scheelite** T540 S985	$CaWO_4$ (Us. also Mo; somet
Ti in HC. sol. w. Sn. See Titanium (1)	Violet col. (Ti) appears before the blue (Cb) when HCl sol. of Pyrochlore is boiled with Sn		**Perovskite** (Perofskite) T487 S722	$CaTiO_3$ (Fe iso. w. Ca)
			Pyrochlore T489 S726	$RCb_2O_6.R(Ti,Th$ (R = Ce, Ca, Na, Fe present)
Cb reac. after fus. w. borax	Turns yel. and gives H_2O in c.t.		Yttrotantalite T492 S738	$(Ca,Fe)(Y,Er)(T$ $.4H_2O$ (Also us. Ce, U, and
	Slight reac. for Cb		Microlite T489 S728	$Ca_2Ta_2O_7$ (Us. also Cb, Na, M

SEC. 29. Nonmetallic luster; st. light; fus. above 5;

Become mag. on ign.	Slowly and dif. sol. in HCl	**IRON ORES** See Section 13	
	Cr in s.ph. bd. (Cp. picotite)	**CHROMITE** (Chromic Iron) T341 S228	$FeCr_2O_4$ (Mg iso. w. Fe; Al and Fe''' iso. w. (
(Continued next page)	Cleav. and prism angles 88° and 92°; often has a metalloidal luster	**Hyperstheme** T385 S348	$(Mg,Fe)_2SiO_3$

	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Blue, grn., gry., wh.	Vitr. to pearly	5–7.25	3.56–3.67	Tri.; us. bladed	C. pinac. per. P. basal F. Splint
	Wh., gryh., redh.	Vitreous	3.5–4	2.58–2.75	Hex. rhom.	C. basal F. uneven
	Wh., yelh., redh., brnh.	Pearly, dull	1–2.5	2.6–2.63	Mon.; us. clay-like	C. basal, per. F. earthy
)	Wh., gry., yel., red	Dull, earthy	1–3	2.55	Mass; clay-like	Oolitic; earthy
	Wh., gryh., grnh., redh.	Vitr., dull C. pearly	2.5–3.5	2.3–2.4	Mon.	C. basal, per.; tough
I_2O	Pale to deep grn., yelh.	Dull to res.	1–4	2.2–2.8	Amorph.; botry.	F. uneven
Cu)	Wh., yel., grn., brn., redh.	Vitr. to adamant.	4.5–5	5.9–6.1	Tetr.	C. pyram. F. uneven
	Yel. & brn. to blk.	Adamant. to sub-met.	5.5	4.017–4.039	Iso.	C. cubic F. uneven
O_3 , F us.	Brn. to redh. and brnh-blk.	Vitr. to res.	5–5.5	4.2–4.36	Iso.; us. oct.	C. oct. F. conch.
,Cb)$_4$O$_{15}$ W)	Yel. to brn. and blk.	Vitr. to submet.	5–5.5	5.5–5.9	Orth.; us. prism.	F. conch.
:, F, H)	Pale yel. to brn.	Res.	5.5	5.48–5.56 (From Va., 6.13)	Iso.; us. oct.	F. conch.

.not alk. after ign.; insol. in HCl; not scratched w. knife.

r)	Fe-blk. to brnh-blk.	Dull to submet.	5.5	4.32–4.57	Iso.; us. mass.	F. uneven
	Grnh-blk. to brn. & bronze	Pearly to bronzy	5–6	3.4–3.5	Orth.; us. mass.	C. pinac. per. F. uneven

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SECTION 29—*Continued*

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

5. Insoluble in HCl or nearly so.

b. Cannot be scratched with a knife; will scratch glass.

		Name.	Compositi
	Cleav. and prism angles 54° and 126°; us. slender prisms, often fibrous (asbestos)	**Anthophyllite** (Asbestos in part) T398 S384	$(Mg,Fe)SiO_3$ (Somet. also Al)
	H_2O in c.t. on intense ign. — Rosettes; foliated; thin scales	Chloritoid T472 S640	$H_2(Fe,Mg)Al_2Si$(
	H_2O in c.t. on intense ign. — Oblong shining scales and plates	Ottrelite T471 S642	$H_2(Fe,Mn)(Al,F$
Blackens b.b. but does not become mag.	Cleav. and prism angles 88° and 92°; often has bronzy, metalloidal luster. (Cp. turquois, which darkens; also the preceding minerals of this section, which do not always become mag.)	**ENSTSATITE** (Bronzite) T 384 S346	$(Mg,Fe)SiO_3$
Whitens b.b. and fus. slightly on intense ign.	B flame w. $KHSO_4$ and CaF_2 (fluorite) on Pt wire; pyroelectric. Achroite cols., indicolite blue, rubellite red	**TOURMALINE** (Schorl; Achroite; Indicolite; Rubellite) T447 S551	$R_{18}(BOH)_2(SiO_5)$ (R = Al, Fe, Mg ch some Mn, Ca, N (F iso. w. OH)
	Whitens at red heat; gives a little H_2O in c.t. on intense ign. (Cp. the next 8 minerals, which also give H_2O)	**BERYL** (Emerald, bright grn.; Aquamarine, pale) T405 S405	$H_2Gl_6Al_4Si_{12}O_{37}$ (Na_2, Li_2, Cs_2 iso. w
H_2O in c.t. on intense ign. if not before. (Cp. beryl, above)	Cu flame; P reac. w. am. mol. after fus. w. soda	**Turquois** T512 S844	$H[Al(OH)_2]_2PO_4$ (CuOH iso. w. Al(O
	Al reac. w. $Co(NO_3)_2$ on ch.	**Diaspore** T348 S246	$AlO(OH)$
	A little H_2O on intense ign. in c.t. Staurolite prismatic and often twinned. (Cp. polycrase, below, which gives a little H_2O)	**Iolite** (Cordierite) T407 S419	$H_2(Mg,Fe)_4Al_8Si$
		STAUROLITE T450 S558	$(AlO)_4(AlOH)Fe$ (Fe iso. w. Al; Mg
	Fus. w. equal amt. of soda on Pt wire to clear glass. Hyalite is cols. and transp.	**OPAL** (Hyalite) T329 S194	$SiO_2 . nH_2O$
	May become mag. Chloritoid us. foliated or hex. plates and scales; ottrelite oblong shining scales and plates	Chloritoid T471 S640	$H_2(Fe,Mg)Al_2Si$(
		Ottrelite T472 S642	$H_2(Fe,Mn)(Al,F$
	Turns yel. in c.t.; Cb reac. after fus. w. borax	Yttrotantalite T492 S738	(Ca,Fe)(Y,Er)(T $4H_2O$ (Also us. Ce, U, an

	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Gry., clove-brn., grn.	Vitreous; C. pearly	5.5–6	3.1–3.2	Orth.; us. fibr. or mass.	C. prism. per.
	Dk. gry., grn., grnh-blk.	Pearly	6.5	3.52–3.57	Tri.; us. fol.	C. basal, per.; brittle
i_2O_9	Grnh-gry., blk.	Vitreous	6–7	3.26–3.3	Tri.	C. basal, per.
	Yelh., gry., brn., grn.	Pearly to bronzy	5.5	3.1–3.3	Orth.; us. mass.	C. prism. F. uneven
r; often . Li, H)	Brn., grn., blue, red, pink, wh., cols.	Vitreous	7–7.5	2.98–3.20	Hex. rhom.; hemimorph. Fig. 51	F. conch to uneven
)	Grn., blue, yel., pink, cols.	Vitr. to res.	7.5–8	2.63–2.80 Us. 2.69–2.70	Hex.; us. xls.	F. conch to uneven
)	Blue, bluish-grn., grn.	Waxy	6	2.6–2.8	Tri.; us. mass.	F. uneven to conch.
	Wh.,gry.,yelh., grnh., brn.	Pearly to vitreous	6.5–7	3.3–3.5	Orth.	C. pianc. per. F. conch.
$_{17}$	Lt. to dk. blue; rarely cols.	Vitreous	7–7.5	2.60–2.66	Orth.	C. pinac. F. conch.
$O_4)_2$ Fe)	Yelh-brn., redh-brn. to brnh-blk.	Res. to vitreous	7–7.5	3.65–3.77	Orth. Figs. 53–55	C. pinac. F. uneven
	Cols., red, yel., grn., blue, gry.	Vitr. to res.	5.5–6.5	1.9–2.3	Amorph.	F. conch.
	Dk. gry., grn., grnh-blk.	Pearly	6.5	3.52–3.57	Tri.; us. fol.	C. basal, per.; brittle
i_2O_9	Grnh-gry., blk.	Vitreous	6–7	3.26–3.3	Tri.	C. basal, per.
$b)_4O_{15}$.)	Yel. to brn. and blk.	Vitr. to submet.	5–5.5	5.5–5.9	Orth.; us. prism.	F. conch.

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SECTION 29—*Continued*

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

5. Insoluble in HCl or nearly so.

b. Cannot be scratched with a knife; will scratch glass.

		Name.	Compositio
Cb reac. after fus. w. borax	Us. Mn reac. in soda bd.	**COLUMBITE** T490 S731	(Fe,Mn)Cb_2O_6 (Also Ta and some S
	Disting. by st. and dull exterior	**Fergusonite** T490 S729	Y(Cb,Ta)O_4 (Er, Ce, U iso. w. Y)
	Glows on ign. and becomes lighter col.; decrepitates and gives trace of H_2O in c.t.	Polycrase T493 S744	Uncertain: Cb, T Ce, Fe, H, O
Little or no Cb; Mn in soda bd.	Fe in s.ph. bd.; very heavy (G. above 6)	Tantalite T490 S731	(Fe,Mn)Ta_2O_6 (Cb iso. w. Ta; sligh
Ti reac. in HCl sol. w. Sn. See Titanium (1)	Xls. us. prismatic, often very slender and twinned	**RUTILE** T345 S237	TiO_2 (Us. a little Fe)
	Xls. us. pyramids	**Octahedrite** (Anatase) T346 S240	TiO_2
	Xls. often tabular	**Brookite** T347 S242	TiO_2
Sn film w. Zn and HCl (see p. 44).	Wh. subl. SnO_2 on intense ign. w. soda on ch.	**CASSITERITE** (Tin Stone) T344 S234	SnO_2
Sp.gr. above 4; Zr test (p. 46)	Glows w. wh. light on intense ign. Hyacinth is transp. red or brown	**ZIRCON** (Hyacinth) T429 S482	$ZrSiO_4$ (Us. a little Fe)
Fus. w. equal amt. of soda on Pt wire to clear glass. (Cp. opal, p. 128)	Xls. us. hex. prisms; agate, jasper, chert, flint, and chalcedony are dense, compact varieties; amethyst, purple	**QUARTZ** (Amethyst; Agate; Jasper; Chalcedony; Chert; Flint) T324 S183	SiO_2
	Xls. us. thin hex. plates	**Tridymite** T328 S192	SiO_2
Wh. enamel w. soda; slowly sol. in borax to clear glass	Dull blue w. $Co(NO_3)_2$ on ch.	**Phenacite** T423 S462	Gl_2SiO_4
Al reac. w. $Co(NO_3)_2$ on ch.	F reac. w. $NaPO_3$ (powdered s.ph. beads) in c.t.	**TOPAZ** T431—S492	$Al(F,OH)_2AlSiO_4$
	Xls. us. stout rectangular	**ANDALUSITE** (Chiastolite) T432 S496	(AlO)$AlSiO_4$
(Continued next page)	Us. fibrous or slender xls.	**SILLIMANITE** (Fibrolite) T433 S498	Al_2SiO_5

..	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
and W)	Fe-blk. to gry. and brnh-blk.	Res. to submet.	6	5.3–6.5	Orth.; us. prism.	F. uneven
	Brnh-blk.	Pale brn.	5.5–6	4.3–5.8	Tetr.; us. mass.	F. uneven
, Y, Er,	Brnh-blk. to blk.	Vitr. to res.	5–6	4.97–5.04	Orth.; us. prism.	F. conch.
Sn & W)	Blk.	Res. to submet.	6	6.5–7.3	Orth.	
	Redh-brn. to blk. & yelh.	Adamant., submet.	6–6.5	4.18–4.25	Tetr.; us. xls.	C. prism. F. uneven
	Brn. to dk-blue and blk.	Adamant., submet.	5.5–6	3.82–3.95	Tetr.; us. pyram.	C. basal and pyram. F. conch.
	Hair-brn. to blk.	Adamant., submet.	5.5–6	3.87–4.08	Orth.; us. xls.	F. uneven
	Brn. to blk.; rarely yel., red., gry., wh.	Adamant.	6–7	6.8–7.1	Tetr. Fig. 39	F. uneven
	Cols., gry., grn., brn., red	Adamant.	7.5	4.2–4.86 Us. 4.68–4.70	Tetr.; us. xls.	C. prism. F. conch.
	Cols., wh., yel., red, grn., blue, brn., blk.	Vitr. to greasy	7	2.60–2.66 Xls. 2.66	Hex. rhom.	F. conch.
	Cols., wh.	Vitreous	7	2.28–2.33	Hex.; tabular	F. conch.
	Cols., wh., yel., rose, brn.	Vitreous	7.5–8	2.97–3.0	Hex. rhom.; us. xls.	C. prism. F. conch.
	Cols., wh., yel., pink, bluish, grnh.	Vitreous	8	3.4–3.6	Orth.	C. basal, per. F. uneven
	Flesh-red, redh-brn., olive-grn.	Vitreous	7.5	3.16–3.20	Orth.; us. prism.	C. prism. F. uneven
	Hair-brn., gry., gryh., grn.	Vitreous	6–7	3.23–3.24	Orth.; us. prism.	C. pinac. per. F. uneven

SECTION 29—*Concluded*

II. Luster not Metallic. Streak light-colored or white.

C. Infusible or nearly so (fus. above 5).

5. Insoluble in HCl or nearly so.

b. Cannot be scratched with a knife; will scratch glass.

		Name	Composi
	Us. bladed xls.; scratched by knife parallel to cleav. but not at right angles to cleav.	**CYANITE** (Disthene) T434 S500	$(AlO)_2SiO_3$
	Extremely hard. Alexandrite is grn. by daylight (and by incandescent gas light); red by lamplight	**Chrysoberyl** (Alexandrite) T342 S229	$GlAl_2O_4$
	Extremely hard. Emery contains magnetite, hematite, or spinel intimately mixed w. corundum	**CORUNDUM** (Sapphire, blue; Ruby, red; Emery, black) T333 S210	Al_2O_3
Cr in s.ph. bd.	Col. blk.; st. dk. brn.; bd. shows Fe reac. while hot and Cr on cooling	**CHROMITE** (Chromic Iron) T341 S228	$FeCr_2O_4$ (Mg iso. w. Fe; A
	Dk. yelh-brn. to grnh-brn. Xls. us. octahedrons	**Pictotite** (Chrome Spinel) T338 S221	(Fe,Mg)(Cr,Al)
	Insol. skeleton of sil. remains in bd. Cp. Garnets, p. 112.	**Uvarovite** (Ca-Cr Garnet) T417 S444	$Ca_3Cr_2(SiO_4)_3$ (Al iso. w. Cr)
Little or no Cr, but fine powder wholly sol. in s.ph. bd. (no silica)	Xls. us. octahedrons, often twins; dark varieties react for Fe	**SPINEL** (Spinel Ruby, red) T338 S220	$MgAl_2O_4$ (Fe, Mn iso. w. M Fe, Cr iso. w. Al
	Wh. ZnO subl. w. soda and borax on ch.; grn. w. $Co(NO_3)_2$	**Gahnite** (Zinc Spinel) T339 S223	$ZnAl_2O_4$ (Mn, Fe iso. w. Zn
	Mag. mass when fused w. a little soda on ch.	**Hercynite** (Iron Spinel) T339 S223	$FeAl_2O_4$
Distinct cl. at 90° or nearly 90°	Fus. about 5	**FELDSPARS** See Section 23	
Extremely hard; not affected by acids or alkalis; burns in O	Xls. us. octahedrons w. curved faces and brilliant adamantine luster. Bort, rough rounded forms, confused xln.; carbonado, massive, dark gray to black	**DIAMOND** (Carbonado; Carbon; Bort) T271 S3	C (Slight ash in Carl

	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Blue, grn., gry., wh.	Vitr. to pearly	5–7.25	3.56–3.67	Tri.; us. bladed	C. pinac. per. P. basal
	Yelh-grn., asparagus-grn. to emerald-grn.	Vitreous	8.5	3.5–3.84	Orth.; us. tab.	C. dome (011) F. uneven, conch.
	Wh., gry., pink., red, yel., grn., blue, brn., blk.	Adamant. to vitr.	9	3.95–4.1	Hex. rhom.	P. basal and rhom. F. uneven
. Cr)	Fe-blk. to brnh-blk.	Dull to submet.	5.5	4.32–4.57	Iso.; us. mass.	F. uneven
	Yelh. or grnh-brn. to brnh-blk.	Pitchy to submet.	7.5–8	4.08–4.11	Iso.; us. mass.	F. uneven
	Emerald-grn.	Vitreous	7.5	3.41–3.52	Iso.	F. conch.
	Red., lavender, blue, grn., brn., blk.	Vitreous	8	3.5–4.1	Iso.; us. oct.	F. conch.
'e w. Al)	Dk., grn., brn. to blk.	Vitreous	7.5–8	4–4.6	Iso.; us. oct.	F. conch., uneven
	Blk.	Vitreous	7.5–8	3.9–3.95	Iso.; us. mass.	F. conch.
ado)	Cols., yel., red, blue, gry., blk.	Adamant. to greasy	10	3.516–3.525	Iso.; us. oct.	C. oct. per. F. conch.

MINERALS ARRANGED ACCORDING TO CRYSTALLIZATION, LUSTER, AND HARDNESS

While arranged primarily on the basis of crystallization, these tables may also be used for the rapid determination of minerals by means of their physical properties, even without crystals. Thus the minerals of a given hardness are quickly found in all the groups and their specific gravities compared. In case two or more are found to have approximately the same hardness and specific gravity, their composition will usually suggest a distinctive test; or the references to the preceding tables may be used for fuller comparison of both physical and chemical properties.

ISOMETRIC: Metallic or Submetallic Luster

Hardness.	Name.	Composition.	Specific Gravity.	Page.
1.5	Lead	Pb	11.37	72
2–2.5	**Argentite**	Ag_2S	7.2–7.36	70
2.5	**GALENA**	PbS	7.4–7.6	70
2.5–3	**GOLD**	Au	15.6–19.33	72
2.5–3	**SILVER**	Ag	10.1–11.1	72
2.5–3	**ELECTRUM**	(Au,Ag)	12.5–15.5	72
2.5–3	**COPPER**	Cu	8.8–8.9	72
2.5–3	**Hessite**	Ag_2Te	8.3–8.5	74
3	**BORNITE**	Cu_3FeS_3	4.9–5.4	70
3	Altaite	PbTe	8.16	76
3–3.5	Amalgam	(Ag,Hg)	13.75–14.1	72
3–4	**TETRAHEDRITE**	$Cu_8Sb_2S_7$	4.4–5.1	68
3–4	**TENNANTITE**	$Cu_8As_2S_7$	4.37–4.49	66
3–4	**Freibergite**	$(Cu,Ag)_8Sb_2S_7$	4.85–5	68
3.5–4	**SPHALERITE**	ZnS	3.9–4.1	70
3.5–4	**CUPRITE**	Cu_2O	5.85–6.15	74
3.5–4	**Pentlandite**	(Fe,Ni)S	4.6	70
3.5–4	**Alabandite**	MnS	3.95–4.04	72
4	**Stannite**	Cu_2FeSnS_4	4.3–4.5	70
4–4.5	**Platinum**	Pt	14–19	80
4–5	**Iron**	Fe	7.3–7.8	76
5.5	**CHROMITE**	$FeCr_2O_4$	4.32–4.57	78
5.5	**Cobaltite**	CoAsS	6–6.3	66
5.5	**Linnaeite**	$(Co,Ni)_3S_4$	4.8–5	70
5.5	**Perovskite**	$CaTiO_3$	4.017–4.039	126
5.5	**Uraninite**	U,Pb,Th,La,Y, etc.	9–9.7	80
5.5	**Gersdorfite**	NiAsS	5.6–6.2	66
5.5–6	**Smaltite**	$CoAs_2$	6.4–6.6	66
5.5–6	**Chloanthite**	$NiAs_2$	6.4–6.6	66
5.5–6.5	**MAGNETITE**	$FeFe_2O_4$	5.17–5.18	76
5.5–6.5	**FRANKLINITE**	$(Fe,Zn,Mn)(Fe,Mn)_2O_4$	5.07–5.22	76
6–6.5	**PYRITE**	FeS_2	4.95–5.1	70
6–7	Martite	Fe_2O_3	4.8–5.3	76
6–7	Iridium	Ir	22.6–22.8	80
6–7	Sperrylite	$PtAs_2$	10.6	66

ISOMETRIC: Nonmetallic Luster

Hardness.	Name.	Composition.	Specific Gravity.	Page.
1-1.5	**Cerargyrite**	AgCl	5.552	86
1-1.5	**Embolite**	Ag(Cl,Br)	5.31-5.81	86
1.5	Arsenolite	As_2O_3	3.70-3.72	80
2	**SYLVITE**	KCl	1.97-1.99	92
2-2.5	**Kalinite**	$KAl(SO_4)_2 \cdot 12H_2O$	1.75	94
2-2.5	**Senarmontite**	Sb_2O_3	5.22-5.3	80
2-3	Bromyrite	AgBr	5.8-6	86
2.5	**HALITE**	NaCl	2.13	92
2.5	**Pharmacosiderite**	$Fe(FeOH)_3(AsO_4)_3 \cdot 6H_2O$	2.9-3	88
3.5-4	**SPHALERITE**	ZnS	3.9-4.1	118
3.5-4	**CUPRITE**	Cu_2O	5.85-6.15	84
4	**FLUORITE**	CaF_2	3.01-3.25	96
5-5.5	**ANALCITE**	$NaAl(SiO_3)_2 \cdot H_2O$	2.22-2.29	102
5-5.5	**Lazurite**	$(Na_2,Ca)_2(AlNaSi_3)Al_2(SiO_4)_3$	2.38-2.45	100
5-5.5	**Pyrochlore**	$RCb_2O_6 \cdot R(Ti,Th)O_3$ (R = Ce, Ca, Na, Fe)	4.2-4.36	126
5.5	**CHROMITE**	$FeCr_2O_4$	4.32-4.57	126
5.5	**Perovskite**	$CaTiO_3$	4.017-4.039	126
5.5	**Noselite**	$Na_4(AlNaSO_4)Al_2(SiO_4)_3$	2.25-2.4	100
5.5	Microlite	$Ca_2Ta_2O_7$	5.48-5.56	126
5.5-6	**LEUCITE**	$KAl(SiO_3)_2$	2.45-2.5	122
5.5-6	**Sodalite**	$Na_4(AlCl)Al_2(SiO_4)_3$	2.14-3	100
5.5-6	**Hauynite**	$CaNa_2(AlNaSO_4)Al_2(SiO_4)_3$	2.4-2.5	100
5.5-6	Danalite	$Gl_3R_3(RS)(SiO_4)_3$ (R = Mn, Fe, Zn)	3.427	100
6-6.5	Helvite	$Gl_3R_3(RS)(SiO_4)_3$ (R = Mn, Fe)	3.16-3.36	100
6-7	Martite	Fe_2O_3	4.8-5.3	86
6.5-7.5	**ANDRADITE**	$Ca_3Fe_2(SiO_4)_3$	3.8-3.9	112
6.5-7.5	**GROSSULARITE**	$Ca_3Al_2(SiO_4)_3$	3.55-3.66	112
7	**Boracite**	$Mg_7Cl_2B_{16}O_{30}$	2.9-3	98
7-7.5	**ALMANDITE**	$Fe_3Al_2(SiO_4)_3$	3.9-4.2	112
7-7.5	**SPESSARTITE**	$Mn_3Al_2(SiO_4)_3$	4-4.3	112
7-7.5	**PYROPE**	$Mg_3Al_2(SiO_4)_3$	3.7-3.75	112
7.5	**Uvarovite**	$Ca_3Cr_2(SiO_4)_3$	3.41-3.52	132
7.5-8	**Gahnite**	$ZnAl_2O_4$	4-4.6	132
7.5-8	Hercynite	$FeAl_2O_4$	3.9-3.95	132
7.5-8	Picotite	$(Fe,Mg)(Cr,Al)_2O_4$	4.08-4.11	132
8	**SPINEL**	$MgAl_2O_4$	3.5-4.1	132
10	**DIAMOND**	C	3.516-3.525	132

TETRAGONAL: Metallic or Submetallic Luster

3.5-4	**CHALCOPYRITE**	$CuFeS_2$	4.1-4.3	70
5-5.5	Hausmannite	Mn_3O_4	4.72-4.856	78
5.5-6	**Octahedrite**	TiO_2	3.82-3.95	130
5.5-6	**Fergusonite**	$Y(Cb,Ta)O_4$	4.3-5.8	130
6-6.5	**RUTILE**	TiO_2	4.18-4.25	130
6-6.5	**Braunite**	$3MnMnO_3 \cdot MnSiO_3$	4.75-4.82	78

TETRAGONAL: Nonmetallic Luster

1-2	Calomel	Hg_2Cl_2	6.482	82
2-2.5	**Torbernite**	$Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$	3.4-3.6	84
2.75-3	**Wulfenite**	$PbMoO_4$	6.7-7	82

TETRAGONAL: Nonmetallic Luster—*Concluded*

Hardness.	Name.	Composition.	Specific Gravity.	Page.
2.75–3	Phosgenite	$(PbCl)_2CO_3$	6–6.3	82
4–5	Xenotime	YPO_4	4.45–4.56	124
4.5–5	APOPHYLLITE	$2H_7KCa_4(SiO_3)_8 \cdot 9H_2O$	2.3–2.4	102
4.5–5	Scheelite	$CaWO_4$	5.9–6.1	110
5	Melilite	$Na_2(Ca,Mg)_{11}(Al,Fe)_4(SiO_4)_9$	2.9–3.1	102
5–6	WERNERITE	$\begin{cases} n(Ca_4Al_6Si_6O_{25}) \cdot \\ m(Na_4Al_3Si_9O_{24}Cl) \end{cases}$	2.66–2.73	114
5.5–6	Octahedrite	TiO_2	3.82–3.95	130
5.5–6	Fergusonite	$Y(Cb,Ta)O_4$	4.3–5.8	130
5.5–6	Meionite	$Ca_4Al_6Si_6O_{25}$	2.7–2.74	104
6–6.5	RUTILE	TiO_2	4.18–4.25	130
6–7	CASSITERITE	SnO_2	6.8–7.1	130
6.5	VESUVIANITE	$Ca_6[Al(OH,F)](Al,Fe)_2SiO_4$	3.35–3.45	114
7.5	ZIRCON	$ZrSiO_4$	4.68–4.7	130

HEXAGONAL: Metallic or Submetallic Luster

1–1.5	MOLYBDENITE (?)	MoS_2	4.7–4.8	78
1–2	GRAPHITE	C	2.09–2.23	78
1.5–2	Tetradymite	$Bi_2(Te,S)_3$	7.2–7.6	76
1.5–2	Covellite	CuS	4.59–4.64	70
2–2.5	Bismuth	Bi	9.7–9.83	72
2–2.5	Tellurium	Te	6.1–6.3	74
2.5	Pyrargyrite	Ag_3SbS_3	5.77–5.86	84
3–3.5	Millerite	NiS	5.3–5.65	70
3–3.5	Antimony	Sb	6.64–6.72	68
3.5	Arsenic	As	5.63–5.73	66
3.5–4.5	PYRRHOTITE	FeS(+S in sol.)	4.58–4.65	70
5–5.5	Niccolite	$NiAs$	7.33–7.67	66
5–6	ILMENITE	$FeTiO_3$	4.5–5	78
5.5–6.5	HEMATITE	Fe_2O_3	4.9–5.3	76
6–7	Iridosmine	(Ir,Os)	19.5–21.2	80

HEXAGONAL: Nonmetallic Luster

1 (?)	Carnotite (?)	K,U,Ca,Ba vanadate	(?)	98
1 (?)	Bismite	$Bi(OH)_3$	4.361	86
1.5	Iodyrite	AgI	5.6-5.7	86
1.5–2	SODA NITER	$NaNO_3$	2.24–2.29	94
2	Chalcophyllite	$Cu(OH)_2[(CuOH)_2AsO_4]_2 \cdot 10H_2O$	2.4–2.66	84
2–2.5	CINNABAR	HgS	8–8.2	82
2–2.5	Proustite	Ag_3AsS_3	5.55	84
2–2.5	Coquimbite	$Fe_2(SO_4)_3 \cdot 9H_2O$	2.1	88
2.5	BRUCITE	$Mg(OH)_2$	2.38–2.4	116
2.5	Pyrargyrite	Ag_3SbS_3	5.77–5.86	84
2.5–3.5	Jarosite	$K[Fe(OH)_2]_3(SO_4)_2$	3.15–3.26	88
2.75–3	Vanadinite	$Pb_4(PbCl)(VO_4)_3$	6.66–7.1	82
3	CALCITE	$CaCO_3$	2.71–2.72	116
3–3.5	Greenockite	CdS	4.9–5	118
3–3.5	Hanksite	$9Na_2SO_4 \cdot 2Na_2CO_3 \cdot KCl$	2.562	92
3.5	Mimetite	$Pb_4(PbCl)(AsO_4)_3$	7–7.25	82

HEXAGONAL: Nonmetallic Luster—*Concluded*

Hardness.	Name.	Composition.	Specific Gravity.	Page.
3.5	Thaumasite	$CaCO_3 \cdot CaSiO_3 \cdot CaSO_4 \cdot 15H_2O$	1.877	116
3.5–4	PYROMORPHITE	$Pb_4(PbCl)(PO_4)_3$	6.5–7.1	82
3.5–4	SIDERITE	$FeCO_3$	3.83–3.88	86
3.5–4	DOLOMITE	$CaMg(CO_3)_2$	2.8–2.9	116
3.5–4	Ankerite	$Ca(Mg,Fe)(CO_3)_2$	2.95–3.1	116
3.5–4	Alunite	$K[Al(OH)_2]_3(SO_4)_2$	2.58–2.75	126
3.5–4.5	RHODOCHROSITE	$MnCO_3$	3.45–3.6	118
3.5–4.5	MAGNESITE	$MgCO_3$	3–3.12	118
3.5–4.5	Breunnerite	$(Mg,Fe)CO_3$	3–3.2	118
4–4.5	ZINCITE	ZnO	5.43–5.7	120
4–5	CHABAZITE	$(Ca,Na_2)Al_2(SiO_3)_4 \cdot 6H_2O$	2.08–2.16	104
4.5	Gmelinite	$(Na_2,Ca)Al_2(SiO_3)_4 \cdot 6H_2O$	2.04–2.17	104
4.5–5	APATITE	$Ca_4(CaF)(PO_4)_3$	3.17–3.23	96
5	SMITHSONITE	$ZnCO_3$	4.3–4.45	118
5	Dioptase	H_2CuSiO_4	3.28–3.35	120
5–5.5	Eudialite	$Na_4Ca_2Zr(SiO_3)_7$	2.9–3	100
5–6	Cancrinite	$H_6Na_6Ca(NaCO_3)_2Al_8(SiO_4)_9$	2.42–2.5	98
5.5	WILLEMITE	Zn_2SiO_4	3.9–4.18	120
5.5	TROOSTITE	$(Zn,Mn)_2SiO_4$	4.11–4.18	100
5.5–6	NEPHELITE	$(Na,K)AlSiO_4$	2.55–2.65	102
5.5–6.5	HEMATITE	Fe_2O_3	4.9–5.3	76
6–6.5	Benitoite	$BaTi(SiO_3)_3$	3.64–3.65	110
7	QUARTZ	SiO_2	2.6–2.66	130
7	Tridymite	SiO_2	2.28–2.33	130
7–7.5	TOURMALINE	$R_{13}(BOH)_2(SiO_5)_4$ (R = Al, Fe, Mg chiefly)	2.98–3.2	108
7.5–8	BERYL	$H_2Gl_6Al_4Si_{12}O_{37}$	2.63–2.8	128
7.5–8	Phenacite	Gl_2SiO_4	2.97–3	130
9	CORUNDUM	Al_2O_3	3.95–4.1	132

ORTHORHOMBIC: Metallic or Submetallic Luster

Hardness.	Name.	Composition.	Specific Gravity.	Page.
1–1.5	Nagyagite	Au,Pb,Sb,Te,S	6.85–7.2	76
1–1.5	Sternbergite	$AgFe_2S_3$	4.1–4.22	70
2	STIBNITE	Sb_2S_3	4.52–4.62	68
2	Bismuthinite	Bi_2S_3	6.4–6.5	72
2–2.5	PYROLUSITE (?)	MnO_2	4.73–4.86	78
2–2.5	Stephanite	Ag_5SbS_4	6.2–6.3	68
2–3	Jamesonite	$Pb_2Sb_2S_5$	5.5–6	68
2.5	Krennerite	$(Au,Ag)Te_2$	8.35	74
2.5–3	CHALCOCITE	Cu_2S	5–5.8	70
2.5–3	Stromeyerite	$(Ag,Cu)_2S$	6.15–6.3	70
2.5–3	Bournonite	$(Pb,Cu_2)_3Sb_2S_6$	5.7–5.9	68
2.5–3	Boulangerite	$Pb_5Sb_4S_{11}$	5.75–6	68
3	Enargite	Cu_3AsS_4	4.43–4.45	66
3–3.5	Zinkenite	$PbSb_2S_4$	5.3–5.35	68
3.5–4	Dyscrasite	Ag_3Sb	9.44–9.85	68
4	MANGANITE	$MnO(OH)$	4.2–4.4	78
5	Glaucodot	$(Co,Fe)AsS$	5.9–6.01	66
5–5.5	GOETHITE	$FeO(OH)$	4–4.4	76
5–5.5	Löllingite	$FeAs_2$ to Fe_3As_4	7–7.4	66
5–5.5	Yttrotantalite	$(Ca,Fe)(Y,Er)(Ta,Cb)_4O_{15} \cdot 4H_2O$	5.5–5.9	126

ORTHORHOMBIC: Metallic or Submetallic Luster—*Concluded*

Hardness.	Name.	Composition.	Specific Gravity.	Page.
5–6	Samarskite	$R''_3R'''_2(Nb,Ta)_6O_{21}$ (R'' = Fe,Ca,UO_2; R''' = Ce,Y, etc.)	5.6–5.8	110
5.5–6	**ARSENOPYRITE**	$FeAsS$	5.9–6.2	66
5.5–6	**Brookite**	TiO_2	3.87–4.08	130
5.5–6	**Ilvaite**	$CaFe_2(FeOH)(SiO_4)_2$	3.99–4.05	74
6	**COLUMBITE**	$(Fe,Mn)Cb_2O_6$	5.3–6.5	130
6	Pseudobrookite	$Fe_4(TiO_4)_3$	4.4–4.98	76
6	Tantalite	$(Fe,Mn)Ta_2O_6$	6.5–7.3	130
6–6.5	**MARCASITE**	FeS_2	4.85–4.9	70

ORTHORHOMBIC: Nonmetallic Luster

1	**Carnallite**	$KMgCl_3 \cdot 6H_2O$	1.6	92
1-2	Molybdite	$Fe_2(MoO_4)_3 \cdot 7H_2O$	4.5	98
1.5-2.5	**SULPHUR**	S	2.05–2.09	80
2	**NITER**	KNO_3	2.09–2.14	94
2-2.5	**Epsomite**	$MgSO_4 \cdot 7H_2O$	1.751	94
2-2.5	**Autunite**	$Ca(UO_2)_2(PO_4)_2 \cdot 8H_2O$	3.05–3.19	96
2-2.5	Goslarite	$ZnSO_4 \cdot 7H_2O$	1.9–2.1	118
2–3	**Thenardite**	Na_2SO_4	2.68–2.69	94
2.5–3	**Valentinite**	Sb_2O_3	5.566	80
2.5–3	**Celadonite**	$[(Pb,Cu)OH]_2SO_4$	6.4	82
2.5–3.5	**BARITE**	$BaSO_4$	4.3–4.6	96
2.75–3	**ANGLESITE**	$PbSO_4$	6.3–6.39	82
3	**Astrolhyllite**	$R'_4R''_4Ti(SiO_4)_4$ (R' = K, Na, H; R'' = Fe, Mn, Mg, Ca)	3.3–3.4	88
3	**Olivenite**	$Cu(CuOH)AsO_4$	4.1–4.4	84
3	Sussexite (?)	$H(Mn,Mg,Zn)BO_3$	3.42	98
3–3.5	**CERUSITE**	$PbCO_3$	6.46–6.57	82
3–3.5	**CELESTITE**	$SrSO_4$	3.95–3.97	96
3–3.5	**ANHYDRITE**	$CaSO_4$	2.9–2.99	94
3–3.5	**Atacamite**	$Cu(CuCl)(OH_3)$	3.75–3.77	84
3–3.75	**WITHERITE**	$BaCO_3$	4.27–4.35	94
3–4	**Wavellite**	$(AlOH)_6(PO_4)_4 \cdot 9H_2O$	2.32–2.34	124
3.5	**Adamite**	$Zn(ZnOH)AsO_4$	4.34–4.35	98
3.5	**Descloizite**	$(Pb,Zn)[(Pb, Zn)OH]VO_4$	5.9–6.2	82
3.5–4	**ARAGONITE**	$CaCO_3$	2.93–2.95	116
3.5–4	**STRONTIANITE**	$SrCO_3$	3.68–3.71	116
3.5–4	**Brochantite**	$[Cu(OH)_2]_3CuSO_4$	3.907	84
3.5–4	**Scorodite**	$FeAsO_4 \cdot 2H_2O$	3.1–3.3	88
3.5–4	Euchroite	$Cu(CuOH)AsO_4 \cdot 3H_2O$	3.389	84
3.5–4	Dufrenite	$Fe_2(OH)_3PO_4$	3.2–3.4	88
4	**Libethenite**	$Cu(CuOH)PO_4$	3.6–3.8	84
4	Variscite	$AlPO_4 \cdot 2H_2O$	2.4	124
4–4.5	Purpurite (?)	$2(Fe,Mn)PO_4 \cdot H_2O$	3.4	96
4.5–5	**CALAMINE**	$(ZnOH)_2SiO_3$	3.4–3.5	98
4.5–5	**Triphylite**	$LiFePO_4$	3.49–3.56	88
4.5–5	**Lithiophylite**	$LiMnPO_4$	3.42–3.56	96
4.5–5	**Childrenite**	$FeAl(OH)_2PO_4 \cdot H_2O$	3.18–3.24	88
5–5.5	**NATROLITE**	$Na_2Al(AlO)(SiO_3)_3 \cdot 2H_2O$	2.2–2.25	98
5–5.5	**GOETHITE**	$FeO(OH)$	4–4.4	76
5–5.5	**Thomsonite**	$(Ca,Na_2)_2Al_4(SiO_4)_4 \cdot 5H_2O$	2.3–2.4	100

ORTHORHOMBIC: Nonmetallic Luster—*Concluded*

Hardness.	Name.	Composition.	Specific Gravity.	Page.
5–5.5	Yttrotantalite	$(Ca,Fe)(Y,Er)(Ta,Cb)_4O_{15}\cdot 4H_2O$	5.5–5.9	126
5–6	**Hypersthene**	$(Mg,Fe)SiO_3$	3.4–3.5	90
5–6	Samarskite	$R''_3R'''_2(Nb,Ta)_6O_{21}$ (R'' = Fe, Ca, UO_2; R''' = Ce and Y metals)	5.6–5.8	110
5–6	Polycrase	Cb,Ti,Y,Er,Ce,F,H,O	4.97–5.04	130
5.5	**ENSTATITE**	$(Mg,Fe)SiO_3$	3.1–3.3	112
5.5–6	**Anthophyllite**	$(Mg,Fe)SiO_3$	3.1–3.2	112
5.5–6	**Brookite**	TiO_2	3.87–4.08	130
5.5–6	**Tephroite**	Mn_2SiO_4	4–4.12	100
5.5–6	**Ilvaite**	$CaFe_2(FeOH)(SiO_4)_2$	3.99–4.05	74
6	**COLUMBITE**	$(Fe,Mn)Cb_2O_6$	5.3–6.5	130
6	Tantalite	$(Fe,Mn)Ta_2O_6$	6.5–7.3	130
6–6.5	**PREHNITE**	$H_2Ca_2Al_2(SiO_4)_3$	2.8–2.95	102
6–6.5	**ZOISITE**	$Ca_2(AlOH)Al_2(SiO_4)_3$	3.25–3.37	114
6–6.5	Humite	$Mg_5[Mg(F,OH)]_2(SiO_4)_3$	3.1–3.2	122
6–7	**SILLIMANITE**	Al_2SiO_5	3.23–3.24	130
6.5	**Fayalite**	Fe_2SiO_4	4–4.14	90
6.5–7	**CHRYSOLITE**	$(Mg,Fe)_2SiO_4$	3.27–3.37	122
6.5–7	**Diaspore**	$AlO(OH)$	3.3–3.5	128
7–7.25	**Danburite**	$CaB_2(SiO_4)_2$	2.97–3.02	108
7–7.5	**Iolite**	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$	2.6–2.66	114
7–7.5	**STAUROLITE**	$(AlO)_4(AlOH)Fe(SiO_4)_2$	3.65–3.77	128
7.5	**ANDALUSITE**	$(AlO)AlSiO_4$	3.16–3.2	130
8	**TOPAZ**	$Al(F,OH)_2AlSiO_4$	3.4–3.6	130
8.25	Lawsonite	$Ca[Al(OH)_2]_2(SiO_3)_2$	3.084–3.091	114
8.5	**Chrysoberyl**	$GlAl_2O_4$	3.5–3.84	132

MONOCLINIC: Metallic or Submetallic Luster

1.5–2	**Sylvanite**	$(Au,Ag)Te_2$	7.9–8.3	74
2–2.5	Freieslebenite	$(Pb,Ag_2)_5Sb_4S_{11}$	6.2–6.4	68
2–3	**Polybasite**	$(Ag,Cu)_9SbS_6$	6–6.2	68
3	**Pearceite**	$(Ag,Cu)_9AsS_6$	6.12–6.17	66
3–4	Tenorite	CuO	5.82–6.25	74
4–4.5	**Ferberite**	$FeWO_4$	6.8–7.11	74
5–5.5	**WOLFRAMITE**	$(Fe,Mn)WO_4$	7.2–7.5	74
5.5–6	**Allanite**	$R''_2R'''_3(OH)(SiO_4)_3$ (R'' = Ca, Fe; R''' = Al, Fe, and Ce metals)	3–4.2	74

MONOCLINIC: Nonmetallic Luster

1–1.5	**Vermiculite (?)**	H,Mg,Fe,Al silicate	2.2–2.3	102
1–1.5	**Natron**	$Na_2CO_3\cdot 10H_2O$	1.42–1.46	92
1–1.5	**Kermesite**	Sb_2S_2O	4.5–4.6	80
1–2	Aluminite	$Al_2(OH)_4SO_4\cdot 7H_2O$	1.66	118
1–2.5	**TALC**	$H_2Mg_3(SiO_3)_4$	2.55–2.8	114
1–2.5	**CHLORITE**	H,Mg,Fe,Al silicate	2.6–2.96	106
1–2.5	**KAOLINITE**	$H_4Al_2Si_2O_9$	2.6–2.63	126
1.5–2	**GYPSUM**	$CaSO_4\cdot 2H_2O$	2.31–2.33	94

MONOCLINIC: Nonmetallic Luster—*Continued*

Hardness.	Name.	Composition.	Specific Gravity.	Page.
1.5–2	**ORPIMENT**	As_2S_3	3.4–3.5	80
1.5–2	**REALGAR**	AsS	3.556	80
1.5–2	**Vivianite**	$Fe_3(PO_4)_2 \cdot 8H_2O$	2.58–2.68	88
1.5–2	**Mirabilite**	$Na_2SO_4 \cdot 10H_2O$	1.481	94
1.5–2	Alunogen	$Al_2(SO_4)_3 \cdot 18H_2O$	1.6–1.8	118
1.5–2.5	**Erythrite**	$Co_3(AsO_4)_2 \cdot 8H_2O$	2.948	88
1.5–2.5	**Annabergite**	$Ni_3(AsO_4)_2 \cdot 8H_2O$	(?)	88
2	**Melanterite**	$FeSO_4 \cdot 7H_2O$	1.89–1.9	88
2	**Aurichalcite**	$2(Zn,Cu)CO_3 \cdot 3(Zn,Cu)(OH)_2$	3.54–3.64	118
2	Thomsenolite	$NaCaAlF_6 \cdot H_2O$	2.93–3	96
2–2.5	**MUSCOVITE**	$H_2KAl_3(SiO_4)_3$	2.76–3	106
2–2.5	**BORAX**	$Na_2B_4O_7 \cdot 10H_2O$	1.69–1.72	96
2–2.5	Kämmererite	$H_8(Mg,Fe)_5(Al,Cr)_2Si_3O_{18}$	2.65–3.1	106
2–2.5	Pharmacolite	$HCaAsO_4 \cdot 2H_2O$	2.64–2.73	98
2–2.5	Liroconite	$[CuAl(OH)_5]_2Cu_6Al(AsO_4)_5.20H_2O$	2.88–2.98	84
2–3	**Gay-Lussite**	$Na_2Ca(CO_3)_2 \cdot 5H_2O$	1.93–1.95	94
2.5	**CRYOLITE**	Na_3AlF_6	2.95–3	96
2.5	**Cookeite**	$Li[Al(F,OH)_2](SiO_3)_2$	2.7	106
2.5	**Linarite**	$[(Pb,Cu)OH]_2SO_4$	5.3–5.45	82
2.5	Leadhillite	$Pb_2(PbOH)_2(CO_3)_2SO_4$	6.26–6.44	82
2.5	**Copiapite**	$Fe_2(FeOH)_2(SO_4)_5 \cdot 17H_2O$	2.103	88
2.5–3	**PHLOGOPITE**	$[H,K,Mg(F,OH)]_3Mg_3Al(SiO_4)_3$	2.78–2.85	106
2.5–3	**BIOTITE**	$(K,H)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$	2.7–3.1	106
2.5–3	**Trona**	$Na_2CO_3 \cdot HNaCO_3 \cdot 2H_2O$	2.11–2.14	92
2.5–3	**Clinoclasite**	$(CuOH)_3AsO_4$	4.19–4.37	84
2.5–3	**Crocoite**	$PbCrO_4$	5–6.1	82
2.5–3	**Polyhalite**	$K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$	2.77–2.78	94
2.5–3	**Glauberite**	$Na_2Ca(SO_4)_2$	2.7–2.85	94
2.5–3	Kainite	$MgSO_4 \cdot KCl \cdot 3H_2O$	2.067–2.188	92
2.5–3	Paragonite	$H_2NaAl_3(SiO_4)_3$	2.78–2.9	106
2.5–3	Zinnwaldite	$(K,Li)_3Fe(AlO)[Al(F,OH)_2]Al(SiO_3)_5$	2.82–3.2	106
2.5–3.5	**Gibbsite**	$Al(OH)_3$	2.3–2.4	126
2.5–4	**LEPIDOLITE**	$LiK[Al(OH,F)_2]Al(SiO_3)_3$	2.8–2.9	106
3	**LEPIDOMELANE**	$(K,H)_2Fe_3(Fe,Al)_4(SiO_4)_5$	3–3.2	106
3	Pachnolite	$NaCaAlF_6 \cdot H_2O$	2.93–3	96
3.5	Hydromagnesite	$Mg_2(MgOH)_2(CO_3)_3 \cdot 3H_2O$	2.15	118
3.5–4	**MALACHITE**	$(CuOH)_2CO_3$	3.9–4.03	84
3.5–4	**AZURITE**	$Cu(CuOH)_2(CO_3)_2$	3.77–3.83	84
3.5–4	**STILBITE**	$H_4(Ca,Na_2)Al_2(SiO_3)_6 \cdot 4H_2O$	2.1–2.2	104
3.5–4	**HEULANDITE**	$H_4(Ca,Na_2)Al_2(SiO_3)_6 \cdot 3H_2O$	2.18–2.22	104
3.5–4	**Laumontite**	$H_4Ca(AlO)_2(SiO_3)_4 \cdot 2H_2O$	3.25–3.36	100
3.5–4.5	**Margarite**	$H_2CaAl_4Si_2O_{12}$	2.99–3.08	124
4	Barytocalcite	$CaBa(CO_3)_2$	3.64–3.66	116
4–4.5	**Ferberite**	$FeWO_4$	6.8–7.11	74
4–4.5	**Colemanite**	$HCa(BO_2)_3 \cdot 2H_2O$	2.42	98
4–4.5	Phillipsite	$2(Ca,K_2,Na_2)Al_2(SiO_3)_4 \cdot 9H_2O$	2.2	104
4–5	**Seybertite**	$H_3(Mg,Ca)_5Al_5Si_2O_{18}$	3–3.1	124
4.5	**Harmotome**	$H_2(Ba,K_2)Al_2(SiO_3)_5 \cdot 4H_2O$	2.44–2.5	104
4.5–5	**WOLLASTONITE**	$CaSiO_3$	2.8–2.9	104
4.5–5	**Triplite**	$R(RF)PO_4$ (R = Fe, Mn, Ca, Mg)	3.44–3.8	88
5	**Pectolite**	$HNaCa_2(SiO_3)_3$	2.68–2.78	100
5	**Mesolite**	$Na_2Ca_2Al_2(AlO)_2(SiO_3)_9 \cdot 8H_2O$	2.2–2.4	100

MONOCLINIC: Nonmetallic Luster—*Concluded*

Hardness.	Name.	Composition.	Specific Gravity.	Page.
5	Herderite	$Ca[Gl(F,OH)]PO_4$	2.99–3.01	114
5–5.5	**MONAZITE**	$(Ce,La,Nd,Pr)PO_4$	4.9–5.3	124
5–5.5	**DATOLITE**	$Ca(BOH)SiO_4$	2.9–3	98
5–5.5	**TITANITE**	$CaTiSiO_5$	3.4–3.56	110
5–5.5	**WOLFRAMITE**	$(Fe,Mn)WO_4$	7.2–7.5	74
5–5.5	Hübnerite	$MnWO_4$	6.89–7.35	110
5–5.5	**Scolecite**	$CaAl[Al(OH)_2](SiO_3)_3 \cdot 2H_2O$	2.16–2.4	100
5–5.5	Wagnerite	$Mg(MgF)PO_4$	3.07–3.14	96
5–6	**DIOPSIDE**	$CaMg(SiO_3)_2$	3.2–3.38	112
5–6	**PYROXENE**	$Ca(Mg,Fe)(SiO_3)_2$	3.1–3.5	112
5–6	**AUGITE**	Like Pyroxene +Na,Al,Fe‴	3.26–3.43	114
5–6	**TREMOLITE**	$CaMg_3(SiO_3)_4$	2.9–3.1	112
5–6	**ACTINOLITE**	$Ca(Mg,Fe)_3(SiO_3)_4$	3–3.02	112
5–6	**HORNBLENDE**	Like Actinolite +Na,Al,Fe‴	3.05–3.47	112
5–6	**Jeffersonite**	$(Ca,Mn)(Mg,Fe,Zn)(SiO_3)_2$	3.4–3.6	110
5–6	**Lazulite**	$(Mg,Fe)(AlOH)_2(PO_4)_2$	3.05–3.12	124
5–6	Hedenbergite	$CaFe(SiO_3)_2$	3.5–3.58	112
5–6	Schefferite	$(Ca,Mn)(Mg,Fe)(SiO_3)_2$	3.5	110
5.5–6	Richterite	$(Mg,Mn,Ca,Na_2)_4(SiO_3)_4$	3.09	110
5.5–6	**Allanite**	$R''_2R'''_3(OH)(SiO_4)_3$ (R'' =Ca, Fe; R''' =Al, Fe, and Ce metals)	3–4.2	74
6	**ORTHOCLASE**	$KAlSi_3O_8$	2.57	108
6	Arfvedsonite	$[(Na,K)_2Ca,Fe]SiO_3$	3.44–3.45	92
6	Riebeckite	$Na_2Fe'''_2(Fe'',Ca)(SiO_3)$	3.433	92
6–6.5	**Acmite**	$NaFe'''(SiO_3)_2$	3.5–3.55	114
6–6.5	**Petalite**	$LiAl(Si_2O_5)_2$	2.39–2.46	108
6–6.5	**Chondrodite**	$Mg_3[Mg(F,OH)]_2(SiO_4)_2$	3.1–3.2	122
6–6.5	Clinohumite	$Mg_7[Mg(F,OH)]_2(SiO_4)_4$	3.1–3.2	122
6–6.5	**Glaucophane**	$Na_2Al_2(SiO_3)_4 \cdot (Mg,Ca,Fe)SiO_3$	3.1–3.11	112
6–7	**EPIDOTE**	$Ca_2(AlOH)(Al,Fe)_2(SiO_4)_3$	3.25–3.5	114
6.5	**Piedmontite**	$Ca_2(AlOH)(Al,Mn,Fe)_2(SiO_4)_3$	3.404	110
6.5–7	**SPODUMENE**	$LiAl(SiO_3)_2$	3.13–3.2	108
6.5–7	**Jadeite**	$NaAl(SiO_3)_2$	3.33–3.35	114
6.5–7	**Gadolinite**	$Be_2Fe(YO)_2(SiO_4)_2$	4–4.5	102

TRICLINIC: Nonmetallic Luster

Hardness.	Name.	Composition.	Specific Gravity.	Page.
1	Sassolite	$B(OH)_3$	1.48	98
2.5	**Chalcanthite**	$CuSO_4 \cdot 5H_2O$	2.12–2.3	84
5–6	**ANDESINE**	$n(NaAlSi_3O_8) \cdot m(CaAl_2Si_2O_8)$	2.68–2.69	108
5–6	**LABRADORITE**	$n(NaAlSi_3O_8) \cdot m(CaAl_2Si_2O_8)$	2.7–2.73	108
5–7.25	**CYANITE**	$(AlO)_2SiO_3$	3.56–3.67	132
5.5–6.5	**RHODONITE**	$MnSiO_3$	3.4–3.68	110
5.5–6.5	Fowlerite	$(Mn,Zn)SiO_3$	3.67	110
6	**Turquois**	$H[Al(OH)_2]_2PO_4$	2.6–2.8	128
6	**Amblygonite**	$Li(AlF)PO_4$	3.01–3.09	108
6–6.5	**MICROCLINE**	$KAlSi_3O_8$	2.54–2.57	108
6–6.5	**ALBITE**	$NaAlSi_3O_8$	2.62–2.65	108
6–6.5	**OLIGOCLASE**	$n(NaAlSi_3O_8) \cdot m(CaAl_2Si_2O_8)$	2.65–2.67	108
6–6.5	**ANORTHITE**	$CaAl_2Si_2O_8$	2.74–2.76	108
6–7	Ottrelite	$H_2(Fe,Mn)(Al,Fe)_2Si_2O_9$	3.26–3.3	128

TRICLINIC: Nonmetallic Luster—*Concluded*

Hardness.	Name.	Composition.	Specific Gravity.	Page.
6.5	Chloritoid	$H_2(Fe,Mg)Al_2SiO_7$	3.52–3.57	128
6.5–7	**Axinite**	$Ca_7Al_4B_2(SiO_4)_8$	3.27–3.35	108
7.25	**CYANITE**	$(AlO)_2SiO_3$	3.56–3.67	132
AMORPHOUS OR CRYSTALLIZATION UNKNOWN: Metallic or Submetallic Luster				
0	Mercury	Hg	13.596	72
1–6	**WAD**	MnO,MnO_2,H_2O,Fe,Si, etc.	3–4.26	78
2–2.5	**PYROLUSITE**	MnO_2	4.73–4.86	78
2.5	**Calaverite**	$(Au,Ag)Te_2$	9.04	76
2.5–3	**Petzite**	$(Ag,Au)_2Te$	8.7–9.02	74
3–3.5	Domeykite	Cu_3As	7.2–7.75	66
3–6	**WAD**	MnO,MnO_2,H_2O,Fe,Si, etc.	3–4.26	78
3.5	Whitneyite	Cu_9As	8.4–8.6	66
4	Algodonite	Cu_6As	7.62	66
5–5.5	**LIMONITE**	$Fe_2(OH)_6Fe_2O_3$	3.6–4	86
5–6	**PSILOMELANE**	$(H_2,Mn)_2MnO_5$	3.7–4.7	78
5–6	**WAD**	MnO,MnO_2,H_2O,Fe,Si, etc.	3–4.26	78
5–6	**Turgite**	$[FeO(OH)]_2Fe_2O_3$	4.14–4.6	86
AMORPHOUS OR CRYSTALLIZATION UNKNOWN: Nonmetallic Luster				
1	**Ulexite**	$NaCaB_5O_9 \cdot 8H_2O$	1.65	96
1	**Carnotite**	K,U,Ca,Ba vanadate	(?)	98
1	Saponite	$Mg_4Al(OH)_2(SiO_3)_5 \cdot 14H_2O$	2.24–2.3	124
1	Nitrocalcite	$Ca(NO_3)_2 \cdot nH_2O$	(?)	94
1–1.5	**Vermiculite**	H,Mg,Al silicate	2.2–2.3	102
1–2	**PYROPHYLLITE**	$H_2Al_2(SiO_3)_4$	2.8–2.9	124
1–2	Halloysite	$H_4Al_2Si_2O_9 \cdot nH_2O$	2–2.2	122
1–2	Hydrocuprite	Hydrous Cu oxide	(?)	84
1–2.5	Asbolite	Co,Mn oxides	3.15–3.29	120
1–2.5	**TALC**	$H_2Mg_3(SiO_3)_4$	2.55–2.8	114
1–3	**BAUXITE**	$Al_2O(OH)_4$	2.55	126
1–4	**Garnierite**	$H_2(Ni,Mg)SiO_4 \cdot nH_2O$	2.2–2.8	126
1–6	**WAD**	MnO,MnO_2,H_2O,Fe,Si, etc.	3–4.26	120
2	Massicot	PbO	7.83–9.36	82
2–2.5	Sepiolite	$H_4Mg_2Si_3O_{10}$	2	102
2–2.5	Hydrozincite	$ZnCO_3 \cdot 2Zn(OH)_2$	3.58–3.8	118
2–3.5	**Deweylite**	$H_4Mg_4(SiO_4)_3 \cdot 2H_2O$	2–2.2	102
2–4	**Chrysocolla**	$CuSiO_3 \cdot 2H_2O$	2–2.24	122
2.5–4.5	Choropal	$H_6Fe_2(SiO_4)_3 \cdot 2H_2O$	1.73–1.87	122
2.5–5	**SERPENTINE**	$H_4(Mg,Fe)_3Si_2O_9$	2.5–2.65	102
3	**Allophane**	$Al_2SiO_5 \cdot 5H_2O$	1.85–1.89	122
3	Sussexite	$H(Mn,Mg,Zn)BO_3$	3.42	98
3–3.25	**Zaratite**	$(NiOH)_2CO_3 \cdot Ni(OH)_2 \cdot 4H_2O$	2.6–2.7	118
3–6	**WAD**	MnO,MnO_2,H_2O,Fe,Si, etc.	3–4.26	120
3.5	Howlite	$Ca(BO \cdot OH)_5SiO_4$	2.55–2.59	108
4	Crocidolite	$NaFe'''(Fe'',Mg)(SiO_3)_3$	3.2–3.3	92
4–4.5	Bismutite	$BiOBi(OH)_2CO_3$	6.86–7.67	86
4–4.5	Purpurite	$2(Fe,Mn)PO_4 \cdot H_2O$	3.4	96
4–5	**SERPENTINE**	$H_4(Mg,Fe)_3Si_2O_9$	2.5–2.65	102
5–5.5	**LIMONITE**	$Fe_2(OH)_6Fe_2O_3$	3.6–4	86
5–6	**WAD**	MnO,MnO_2,H_2O,Fe,Si, etc.	3–4.26	120
5–6	**Turgite**	$[FeO(OH)]_2Fe_2O_3$	4.14–4.6	86
5.5–6.5	**OPAL**	$SiO_2 \cdot nH_2O$	1.9–2.3	128

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TABLES FOR THE DETERMINATION

OF THE

COMMON MINERALS AND ROCKS

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INTRODUCTION

A mineral may be defined as any inorganic substance found in nature that has a definite chemical composition. Minerals usually have a definite crystalline structure, also, but this is not essential, as is shown in the case of limonite, bauxite, and psilomelane. The tables include all the very common minerals and also a number that are less abundant, altho some of them may be very important as the source of some of the metals, such as galena, sphalerite, stibnite, hematite, etc.

It is possible to determine the names of the various minerals by the use of their physical properties. The most important properties are streak, color, luster, hardness, cleavage, fracture, structure, specific gravity, and more rarely, odor, taste, feel, and magnetism. It is always necessary to make these determinations upon a fresh specimen, because minerals are changed by the action of water, gases, temperature, etc. But by using care, the minerals which are similar in some properties but different in others, can be separated.

The streak of a mineral is the color of its powder. This may be obtained by rubbing it upon a streak plate or by scratching or breaking up a fragment and noting the color. Fresh material must be used. The streak is the first property determined.

The color of a mineral may always be the same, or it may range thru various shades of one color, or the same mineral may have several different colors.

Luster is defined as the appearance of the surface in reflected light. Minerals are divided into two groups on the basis of their luster, viz., metallic and non-metallic. Minerals with a metallic luster reflect light like a metal. There are various lusters in the non-metallic group, common ones being vitreous, greasy, earthy, waxy, adamantine, resinous, etc. These are defined in the glossary.

Hardness is the resistance a mineral offers to scratching. Use a good knife (a good knife blade usually has a hardness of about 5.5) or compare the mineral to another of known hardness. This is done by seeing which one in the known scale will scratch it. The common scale of hardness is as follows: 1—talc, 2—gypsum, 3—calcite, 4—fluorite, 5—apatite, 6—orthoclase, 7—quartz, 8—topaz, 9—corundum, 10—diamond. Fibrous or finely granular minerals usually appear softer than the individual fibers or grains really are. Use the same pressure for all the minerals. In the group where the streak is white or light gray, the minerals are grouped according to their hardness.

Cleavage is the property of minerals to break or split easily along certain planes in the mineral. These planes are parallel to each other and are also parallel to some possible crystal face. Thus a mineral with cubic cleavage splits parallel to the cube faces, etc. There are various degrees of cleavage which may be called perfect, imperfect, good, fair, or poor.

Fracture is that character of the surface obtained when a mineral is broken in any direction other than that parallel to the cleavage. There are several fractures as follows: conchoidal, uneven, splintery, hackly, smooth, and earthy.

The various ways in which minerals can occur are known as structures. The great majority of minerals do not show crystal forms but occur in masses or aggregates. Various terms are in use to define these forms, the following being the most important; bladed, botryoidal, columnar, compact, crested, fibrous, foliated, lamellar, prismatic, mammillary, and stalactitic.

The specific gravity of a mineral is its weight compared to that of an equal volume of water. This can be roughly determined by the use of the Jolly specific gravity balance, or on any balance.

Some minerals have a distinct odor after they have been moistened or rubbed. Kaolin has an earthy odor after moistening by breathing upon it; pyrite gives off a sulfurous odor on being struck, etc.

Those minerals which are soluble in water can be tasted. Salt or halite is a very common example of these.

Various minerals feel smooth, soapy, clayey, or rough to the touch.

A few minerals are attracted by a magnet, and one variety of magnetite acts as a lodestone or magnet itself.

For further definitions see the glossary.

Do not expect to find every property listed in the tables perfectly developed on each mineral. Such a case would be unusual, altho in most cases there will be a sufficient number of physical properties to determine the mineral easily.

GLOSSARY

Adamantine luster—like that of the diamond.
Basal cleavage—splits parallel to the end or base of a crystal.
Bladed—elongated or flattened, like the blade of a knife.
Botryoidal—closely united spherical masses, resembling a bunch of grapes.
Cleavage—a property of minerals to break or split easily in certain directions, yielding approximately smooth surfaces.
Columnar—long thick fibers.
Compact—closely united.
Conchoidal—the breaking of a mineral with a rounded or curved surface like the interior of a shell.
Concretion—rounded masses formed about a center.
Crested—flat, parallel crystals with their edges projecting as ridges.
Crystal—Xl—a substance bounded entirely or nearly so, by natural plane faces.
Earthy—looks like clay, dull.
Effervescence—the mineral dissolves, giving off a gas as bubbles.
Fibrous—consists of slender fibers or threads.
Foliated—in plates or leaves that separate easily.
Fracture—any surface obtained when a mineral is broken not parallel to the cleavage.
Hackly—rough surface covered with sharp points.
Iridescence—usually a thin film on the surface of a mineral which produces a play of colors.

Lamella—small, thin plates or layers, curved or straight.
Luster—the manner in which a surface reflects light.
Magnetic—attracted by a magnet.
Metallic luster—reflecting light like a metal.
Prismatic—a crystal elongated parallel to the vertical axis.
Resinous luster—having the appearance of resin.
Stalactites—cylindrical masses, resembling icicles.
Rhombohedral—shaped like a rhomb.
Sectile—capable of having slices cut off.
Tarnish—a thin, colored film on the surface of a mineral. It differs from the color of the mineral.
Vitreous luster—reflects light like glass.
Waxy luster—reflects light like wax, or looks like wax.
Xls—crystals.

KEY TO THE TABLE

1. Streak Black or nearly so, to Steel Gray.
   Color: Dark Gray or Black. Page 6.
   Brass Yellow or Bronze to Purplish. Page 6.
2. Streak Red or Brownish Red. Page 6-8.
   Color: Red or Brown. Page 7.
   Dark Gray or Black. Page 8.
3. Streak Yellow or Yellowish Brown.
   Color: Yellow. Page 8.
   Brown or Black. Page 8.
   Yellowish Green. Page 10.
4. Streak Blue or Green.
   Color: Blue or Green. Page 10.
   Dark Green or Black. Page 10.
5. Streak Uncolored—White or Light Gray.
   Transmits light on thin edges.
   Hardness—1-2.5. Can scratch with the finger nail. Page 10-12.
   Hardness—2.5-5.5 or 6. Will not scratch glass. Pages 12-14.
   Hardness—5.5 to 6 or over. Will scratch glass. Pages 14-18.

STREAK DARK GRAY TO BLACK

H	Color	Streak	Cleavage or Fracture	Luster	G
	COLOR: DARK GRAY TO BLACK				
1-2.5	Steel gray to black	Darker than color	Basal, perfect	Metallic dull	2.2
2	Dark lead gray	Gray, black	Prismatic, gives long, shiny faces	Metallic	4.5
2.5	Dark lead gray	Dark gray to black	Cubic, perfect	Metallic	7.5
2.5-3	Dark lead gray	Lead gray	C—good but rarely seen F—conchoidal to uneven	Metallic	5.5 5.8
5-6	Grayish black; dull black	Brownish to black	F—conchoidal	Submetallic	2.2 4.7
5.5	Iron black	Iron black	F—uneven	Metallic	5.2
	COLOR: BRASS YELLOW TO BRONZE TO PURPLISH				
3	Purplish, copper brown, horse-flesh brown.	Grayish black	F—uneven	Metallic	4.9 5.4
3.5 4	Deep brass yellow	Greenish black	F—uneven to conchoidal	Metallic	4.2
3.5 4.5	Bronze yellow Bronze brown	Grayish black	F—uneven	Metallic	4.6
6 6.5	Pale brass yellow	Greenish black	F—uneven	Metallic	5
6	Whitish brass yellow	Black	F—uneven	Metallic	4.9

STREAK RED OR BROWNISH RED OR BROWN

H	Color	Streak	Cleavage or Fracture	Luster	G
	COLOR: RED OR BROWN				
1.5 3	Reddish to brown	Reddish bwn.	F—earthy	Earthy, dull	2.5
1-4	Brownish red to cherry red	Dark red, cherry-red	F—earthy	Earthy, dull	2.5-5
2.5 3	Copper red	Copper red	F—hackly	Metallic	8.8

STREAK DARK GRAY TO BLACK

Structure	Other Properties	Name and Composition
COLOR: DARK GRAY TO BLACK		
Foliated, laminated, scaly, earthy	Feels greasy; marks paper; sectile; scales flexible, inelastic	Graphite, Carbon
Prisms, often bent; bladed	Brittle; sometimes iridescent; tarnished	Stibnite, Sb_2S_3
Cubes and granular masses	Sectile to brittle; often found with sphalerite	Galena, PbS
X1s rare. Massive or as grains.	Often has a bluish tarnish. Associated with pyrite, chalcopyrite, etc.	Chalcocite, CuS
Massive rounded masses; kidney shaped	Tough to brittle; often found with limonite	Psilomelane, MnO_2H_2O, etc.
Octahedrons, massive, granular to compact	Brittle; strongly magnetic	Magnetite, Fe_3O_4
COLOR: BRASS YELLOW TO BRONZE TO PURPLISH		
Compact; massive	Usually has many colors, but purple predominates; brittle	Bornite, Cu_5FeS_4
Massive; compact; rarely in four-sided crystals	Softer than pyrite, may have a tarnish; brittle	Chalcopyrite, $CuFeS_2$
Massive, granular	Slightly magnetic; surface often tarnished bronze-brown	Pyrrhotite, Fe_7S_8
Cubes, pyritohedrons, massive, granular	Very common. Found everywhere. Cubes are striated. Brittle	Pyrite, FeS_2
Arrow shaped Xls, may have curved faces, stalactites	Never in the form of cubes; white on fresh surface	Marcasite, FeS_2

STREAK RED OR BROWNISH RED OR BROWN

Structure	Other Properties	Name and Composition
COLOR: RED OR BROWN		
Clay like masses with small round concretions	Distinguished from clay by the concretions. Clayey odor	Bauxite, Al_2O_3 $2H_2O$
Compact, granular, earthy, nodules, etc. Powder	Red ochre, looks like red clay, which it may be	Hematite, Fe_2O_3
Hackly masses, sheets, wires, and crystals	Malleable; often with a dark tarnish; sometimes greenish tarnish	Copper, Cu

STREAK RED, OR BROWNISH RED OR BROWN

H	Color	Streak	Cleavage or Fracture	Luster	G
COLOR: RED OR BROWN					
3.5 4	Brown, dark reddish bwn., red, deep red	Reddish bwn.	C—perfect. 12-sided forms	Resinous, vitreous	4
4.5 5	Red to reddish brown	Pale reddish brown	C—basal fair F—conchoidal to uneven	Vitreous, to greasy	3.1
COLOR: DARK GRAY OR BLACK					
2.5 6.5	Dark steel gray to iron black	Brownish-red	C—Micaceous (if present)	Metallic, brilliant	4.4 5.3
3.5 4	Brownish black	Dark brown	C—perfect. 12-sided forms	Resinous, submetallic	4
5-6	Dull black	Very dark brown	F—conchoidal	Submetallic, dull	3.7 4.7
6-7	Black	Dark brown	C—poor	Submet. to metallic	7

STREAK YELLOW, YELLOWISH BROWN TO BROWNISH

H	Color	Streak	Cleavage or Fracture	Luster	G
COLOR: YELLOW					
1.5 2.5	Sulphur yellow, honey yellow, straw yellow	Pale yellow	C—poor F—conchoidal	Resinous, vitreous	2
1.5 4	Yellow	Yellowish brown	C—None F—earthy	Earthy to dull. Silky	3.6
3.5 4	Brownish yellow to yellow	Pale yellow	C—12 sided, perfect F—uneven	Resinous	4
COLOR: BROWN OR BLACK					
1.5 3	Brown or black	Browns or yellow	F—earthy	Earthy to dull	2.5
1.5 4	Brown or black	Brownish yellows	F—earthy	Earthy to dull	3.6
3.5 4	Brown to brownish black	Brownish yellow	C—12 sided perfect F—uneven	Resinous	4
3.5 4	Various shades of brown	Pale yellow, ylw-brwn.	C—rhombohedral, perfect	Vitreous	3.8
6-7	Black, red-brown, yellow-brown	Pale ylw. gray-bwn.,	F—uneven	Submetallic	6.8 7.1

STREAK RED, OR BROWNISH RED OR BROWN

Structure	Other Properties	Name and Composition
COLOR: RED OR BROWN		
Granular masses and crystals with rounded faces	Distinguished by its resinous luster, often with galena	Sphalerite, ZnS
Prismatic Xls usually. Massive, granular.	Xls have a fused appearance.	Apatite (CaF) Ca_4 $(PO_4)_3$
COLOR: DARK GRAY TO BLACK		
Foliated, platy, micaceous, massive granular	Bright sparkling plates or scales. Specular hematite	Hematite, Fe_2O_3
Massive, granular and in crystals	May occur with galena, pyrite and chalcopyrite. See above	Sphalerite, ZnS
Massive, granular, compact, kidney shaped	Tough to brittle. Note dull luster and fracture	Psilomelane, MnO_2H_2O, etc.
Massive, as grains like sand, pebbles	Usually as grains and pebbles. Very hard and heavy	Cassiterite, SnO_2

STREAK YELLOW, YELLOWISH BROWN TO BROWNISH

Structure	Other Properties	Name and Composition
COLOR: YELLOW		
Massive, in crystals and as crusts	Can be ignited with a match and burns with a blue flame	Sulfur, S
Earthy masses and nodules. Radiating	Yellow ochre. Looks like clay; and often is clay	Limonite, $2Fe_2O_33H_2O$
Massive, cleavable masses, crystals	Brittle. Often found with galena and chalcopyrite	Sphalerite, ZnS
COLOR: BROWN OR BLACK		
Clay like masses contain concretions	Has a clay odor, often is hard. See above	Bauxite, $Al_2O_32H_2O$
Massive, earthy Radiating nodules	Brown ochre. See above	Limonite, $2Fe_2O_33H_2O$
Massive, cleavable masses, crystals	Very common color	Sphalerite, ZnS
Rhombohedrons, cleavage masses, crystals	The cleavage or crystal faces are often curved. Brittle.	Siderite, $FeCO_3$
Grains, pebbles with concentric structure	Note the hardness and the gravity. Stream tin.	Cassiterite, SnO_2

STREAK YELLOW, YELLOWISH BROWN TO BROWNISH

H	Color	Streak	Cleavage & Fracture	Luster	G
	COLOR: YELLOWISH GREEN				
6-7	Yellowish green, olive green, nearly black	Pale yellow to white	C—basal, perfect F—uneven	Vitreous	3.3

STREAK BLUE OR GREEN

H	Color	Streak	Cleavage & Fracture	Luster	G
	COLOR: BLUE OR GREEN				
1-2	Dull green, often dark	Greenish whitish	F—earthy	Dull	2.2
1.5 2.5	Grass green to dark green	Pale green gryish grn.	C—basal, perfect	Pearly, dull vitreous	2.8
2-4	Bluish green to greenish blue	Pale green Pale blue	F—uneven to conchoidal	Vitreous, earthy	2 2.3
3.5 4	Bright green, dark green, emerald green	Emerald green	F—uneven, splintery	Vitreous, silky, dull	4
3.5 4	Azure blue	Smalt blue	F—uneven	Vitreous, velvety	3.8
4-6	Light to dark green	Greenish wht. to white.	C—prismatic	Vitreous, silky	2.9 3.2
5-6	Blackish green to leek green	Greenish-gray pale green	C—prismatic, perfect F—uneven	Vitreous submet,	3.2 3.6
5-6	Dark shades of green	Greenish gray yellowish	C—prismatic, perfect F—uneven	Vitreous, silky	2.9 3.3
	COLOR: DARK GREEN TO BLACK				
5-6	Greenish black, pitch blk., brwn-black	Gray, green, brwn-gray	Angle between the faces 124°	Vitreous, silky	2.9 3.3
5-6	Greenish black, pitch-black, to brownish blk.	Greenish-gray to gray	C—Prismatic, good angle between the faces 87°	Vitreous to dull	3.2 3.5

STREAK UNCOLORED. WHITE OR LIGHT GRAY

H	Color	Streak	Cleavage & Fracture	Luster	G
	HARDNESS 1—2.5. CAN SCRATCH WITH FINGER NAIL				
1 1.5	Green, white, gray	White	C—basal, perfect F—uneven to splintery	Silky to greasy, silky metallic	1-2.5
1-2.5	Light to olive-green, yellowish-green.	White	-fibrous	Pearly to greasy	2.6 2.8

STREAK YELLOW, YELLOWISH BROWN TO BROWNISH

Structure	Other Properties	Name and Composition
COLOR: YELLOWISH GREEN		
Slender, striated prisms, massive, fibrous, etc.	Translucent to opaque. Has a peculiar green color	Epidote, Hydrous Ca, Al, Fe, silicate

STREAK BLUE OR GREEN

Structure	Other Properties	Name and Composition
COLOR: BLUE OR GREEN		
Grains or granular massives. Earthy.	Common in green sands. Also as grains in limestones and marls.	Glauconite, Hydrous silicate of K and Fe.
In foliated scaly, granular, earthy masses	Tough to brittle. Flexible but not elastic like the micas.	Chlorite, H_2O, Mg, Al, silicate
Massive, opal-like masses	Brittle. Adheres to the tongue. Usually found with copper ores.	Chrysocolla, $CuSiO_3$ $2H_2O$
Fibrous, banded, stalactitic, botryoidal, masses	Often as a stain on rocks. May be interlayered with azurite. Effervesces with HCl.	Malachite, $CuCO_3$ $Cu(OH)_2$
Crystals, fibrous, banded, acicular	Usually found with malachite. Like malachite.	Azurite, $2CuCO_3$ $Cu(OH)_2$
Long slender crystals, radiating, fibrous	124° is the angle between the cleavage faces	Actinolite, $Ca(MgFe)_3(SiO_3)_4$
Short, thick Xls., 8 sided, granular	Distinguished from hornblende by the 87° angle between faces	Augite, Ca, Mg, Fe, Al, silicate
Long slender Xls, fibrous, blades, granlar	Distinguished by its 6 sided Xls and 124° angle between faces	Hornblende Ca, Mg, Fe, Al, silicate
COLOR: DARK GREEN OR BLACK		
Long slender prisms, 124° between cleavage faces	Common. Determined by the angle between faces as given above	Hornblende, Ca, Mg, Fe, Al, SiO_2
Short thick, 8 sided Xls. Angle 87°	Brittle. Determined by its cleavage angle and 8 sides	Augite, Ca, Mg, Fe Al, silicate

TRANSMIT LIGHT ON THIN EDGES

Structure	Other Properties	Name and Composition
Foliated, fibrous, compact masses	Sectile. Greasy or soapy feel. Inelastic plates. Soapstone when finely granular	Talc, $H_2Mg_3Si_4O_{12}$
Fibrous, rarely massive	Fibers flexible and easily separated. Feels smooth. Beautiful fibers.	Asbestos (chrysotile) $H_4Mg_3Si_2O_9$

STREAK UNCOLORED OR WHITE OR LIGHT GRAY

H	Color	Streak	Cleavage & Fracture	Luster	G
HARDNESS 1-2.5. CAN SCRATCH WITH FINGER NAIL					
1-2	Dull green, often dark	White	F—earthy	Dull	2.2
1-2.5	White, gray, pink and red	White	C—basal, perfect F—conchoidal	Pearly, vitreous, silky dull	2.2 2.4
1.5 2.5	Yellow	White	F—uneven to conchoidal	Vitreous to greasy	2
1.5 2.5	White, yellow, brown, gray	White	F—earthy	Earthy to dull	2.6
1.5 3	Reddish, brownish, yellow, white	White or the same as color	F—earthy	Earthy to dull	2.5
2 2.5	White, gray, yellow, brown	White	C—perfect, into thin sheets	Pearly to vitreous	2.7 3
2-2.5	Black, brown, green	White, gray,	C—perfect, into thin sheets	Pearly to vitreous	2.7 3.1
2-2.5	Dark to grass green	Gray, white, green	C—perfect, as very fine scales	Pearly, vitreous, dull	2.8
2.5 3	White, red, blue, green, gray, etc.	White	C—cubic, perfect F—Conchoidal	Vitreous	2.2
2.5 5	Light and dark green, honey-yellow, white	White	F—uneven to conchoidal, splintery	Waxy, greasy, dull	2.5
HARDNESS 2.5 to 5.5 or 6. WILL NOT STRATCH GLASS					
2.5 3	White, red, blue, green, gray,	White	C—cubic, perfect F—conchoidal	Vitreous	2.2
2.5 5	Light and dark green, honey-yellow, white	White	F—uneven to conchoidal, splintery	Vaxy, greasy dull	2.5
2.5 3.5	White, yellowish, gray pinkish, brown	White	C—basal and prismatic, good F—uneven	Vitreous, pearly	4.5
3	White, pink yellow, red, brown, gray, green	White	C—perfect, cleaves into rhombohedrons, even in very small fragments	Vitreous, pearly, dull	2.7

TRANSMIT LIGHT ON THIN EDGES

Structure	Other Properties	Name and Composition
Grains or granular massive. Earthy	Common in green sands. Also as grains in limestones and marls.	Glauconite, Hydrous silicate of K and Fe.
Tabular, transparent Xls, massive, granular, fibrous	3 varieties of gypsum. Cleaves into thin sheets not flexible or elastic—selenite. Fibrous—satin-spar. Granular massive—alabaster	Gypsum, $CaSO_4 2H_2O$
Crystals, crusts, massive	Brittle. Catches fire easily and burns with a blue flame	Sulfur, S
Massive, compact masses, earthy, soapy, friable	Clay odor when breathed upon. Adheres to the tongue. Plastic, greasy.	Kaolin, $H_4Al_2Si_2O_9$
Massive with pea-shaped concretions	Clay odor, distinguished from kaolin by the pea-shaped masses.	Bauxite, $Al_2O_3 2H_2O$
In plates or books. Sometimes large. As scales	Tough and transparent. Flexible and elastic. Splits easily.	Muscovite, $H_2KAl_3(SiO_4)_4$
In plates or books, scales, micaceous	Tough. Dark colored even in the thinnest sheets. Splits easily. Flexible and elastic	Biotite, Silicate of H, K, Al, Mg, & Fe
Micaceous scaly masses, lusterous	Tough to brittle. Flexible, but not elastic like the micas	Chlorite, H_2O,Mg,Al Silicate
Massive granular masses. Xls.	Tough, Salty taste, soluble in water	Halite (Common Salt) NaCl
Massive, compact, fibrous	Tough, brittle; smooth, greasy feel	Serpentine. $H_4Mg_3Si_2O_9$.

WILL NOT SCRATCH GLASS

Structure	Other Properties	Name and Composition
Massive granular masses. Xls.	Brittle. Salty taste. Soluble in water	Halite (Common Salt), NaCl
Massive, compact, fibrous	Tough, brittle; smooth, greasy feel.	
Tabular, prismatic Xls. Crested or divergent groups. Compact, lamellar	Brittle. Easily determined by its high specific gravity and cleavage. Often found in limestones	Barite (Heavy Spar) $BaSO_4$
Long, sharp Xls and short Xls. Rhombohedrons, massive granular, cleavable masses. Found in cavities in many kinds of rocks	Perfect cleavage into rhombs, easy effervescence with hydrochloric acid make it easy to determine. Transparent to opaque. There are many varieties of calcite	Calcite, $CaCO_3$

STREAK UNCOLORED, WHITE OR LIGHT GRAY

H	Color	Streak	Cleavage & Fracture	Luster	G
HARDNESS—2.5 to 5.5 or 6. WILL NOT SCRATCH GLASS					
3-3.5	White, grayish, bluish-gray, gray, reddish	White	C—perfect in two directions, fair in the third F—uneven	Vitreous to pearly	2.9-3
3.5	Gray, yellowish, brown, white, etc.	White or gray	C—good into rhombohedrons with slightly curved faces	Vitreous pearly dull	2.9
3.5 4	Pink, gray, white, brown	White to gray	C—into rhombohedrons F—conchoidal	Vitreous, pearly,	3.8
3.5 4	Honey-yellow yellowish brown, reddish	White to yellowish	C—perfect into 12 sided forms if complete. Not usual	Greasy, resinous submetallic	3.9 4.2
4	White, yellow, green, pink, purple	White	C—readily into octahedrons or an 8 sided forms	Vitreous	3
3.5 4.5	White, gray, brown	White	C—rhombohedral perfect F—conchoidal when massive	Dull to earthy, rarely vitreous	3 3.1
4.5 5.5	White to gray	White to gray	C—prismatic at an angle of 124°.	Vitreous to silky	2.9 3.2
4.5 5	Green, brown, red, white, gray, etc.	Usually white	C—basal fair F—conchoidal—uneven	Vitreous to greasy	3.1
4-7	Blue, white, bluish gray, reddish and green	White	C—perfect in two directions producing bladed forms F—fibrous	Vitreous, pearly	3.6
HARDNESS Above 5.5 or 6. WILL SCRATCH GLASS					
5-6	Usually dark green or black but may be light green or white	Lighter than the color	C—has perfect cleavage giving an angle of 124° F—uneven	Vitreous to silky	2.9 3.3
5-6	Color usually like the above mineral but lighter	Lighter than the color	C—good, giving an angle of 87° F—uneven	Vitreous to dull bronzy	3.2 3.5

TRANSMIT LIGHT ON THIN EDGES

Structure	Other Properties	Name and Composition
WILL NOT SCRATCH GLASS		
Granular, massive, lamellar or fibrous	Brittle. Looks like marble or sugar. Not so heavy as barite. Acid has no effect.	Auhydrite, $CaSO_4$
Cleavable masses, Xls have curved faces	Brittle. Nearly always some shade of brown. Sp. Gr. Dissolves slowly in hot HCl.	Siderite, $FeCO_3$
Usually has crystal faces which are curved. Granular masses.	Has curved faces and does not effercesce in cold hydrochloric acid unless in a powder	Dolomite, $CaMg(CO_3)_2$
Granular, cleavable masses, Xls	Resinous luster and good cleavage	Sphalerite, ZnS
Very common as cubic Xls, granular; cleaves easily	Transparent to translucent. Easily determined by octahedral cleavage and hardness	Fluorite, CaF_2
Massive, rarely crystalline. As disseminated grains	Conchoidal F, prominent and characteristic.	Magnesite, $MgCO_3$
Prismatic Xls, usually. Massive, granular	Cleavage faces at an angle of 124°	Actinolite, $Ca(MgFe)_3$
Bladed Xls, often radiating, fibrous	Xls have a fused appearance	Apatite, $(CaF)Ca_4(PO_4)_3$
As long blade-like Xls.	Often has bluish spots in the Xls	Cyanite, Al_2SiO_5
NOT SCRATCHED WITH A GOOD KNIFE AS A RULE		
Long, slender crystals. Bladed, fibrous, columnar	May be softer, due to alteration. Six sided crystals. Cleavage angles 124°. Luster brighter than augite, cleavage also better	Hornblende (several varieties). Silicate of Ca, Mg, Fe, Al
Short thick Xls. Compact masses, etc.	Recognized by the shape of the Xls. Cleavage faces at angle of 87°. 8 sided Xls.	Augite. Silicate of Ca, Mg, Fe, Al

STREAK UNCOLORED. WHITE OR LIGHT GRAY

H	Color	Streak	Cleavage & Fracture	Luster	G
HARDNESS ABOVE 5.5 or 6. WILL SCRATCH GLASS.					
5-6	White, light gray to light green, also pink	White	C—perfect at an angle of 124° F—uneven.	Vitreous to silky	2.9 3.1
5-6	White to light or rarely dark green, grayish	White to gray to greenish	C—good in two directions at an angle of nearly 90° F—uneven to conchoidal	Vitreous often dull, rarely pearly	3.2 3.6
5-6	Light to dark green	White to gray	C—prismatic at an angle of 124°	Vitreous to silky	2.9 3.2
4-7	Blue, white, bluish gray, reddish and green	White	C—perfect in two directions producing bladed forms. F—fibrous	Vitreous, pearly	3.6
5.5-6	White, gray, greenish colorless	White	C—poor F—conchoidal to uneven	Vitreous to greasy	2.55 2.65
5.5	White, to gray	White	C—poor F—conchoidal	Vitreous to greasy	2.5
5.5 6	Blue, gray white, greenish, yellowish	White	C—not distinct; if present, dodecahedral F—conchoidal to uneven	Vitreous greasy	2.14 2.30
6	White, pink, red, yellow, green, gray, black	White	C—perfect in two directions at 90° F—uneven, splintery	Vitreous, pearly	2.6
6 6.5	White, yellowish, green	White	C—good in two directions F—uneven	Vitreous, pearly	2.55
6	Gray, often dark, grayish white	White-	C—perfect in 2 directions, nearly 90° F—uneven	Vitreous, glassy	2.7
6-6.5	White, gray, colorless	White to white	C—perfect in 2 directions, nearly 90° F—uneven	Vitreous, pearly glassy	2.6
6-7	Yellowish green, dark green	Grayish, etc.	C—basal, fair, not common F—uneven	Vitreous,	3.3
6.5 7	Various shades of green	White	F—uneven to subconchoidal	Vitreous, glassy	3.2
6.5 7.5	Red, brown, yellow, pink, etc. black	Usually colored light	F—uneven to conchoidal	Vitreous, Rarely resinous	3.4 4.3

TRANSMIT LIGHT ON THIN EDGES

NOT SCRATCHED WITH A GOOD KNIFE AS A RULE

Structure	Other Properties	Name and Composition
Xls, usually long bladed or short and stout. In long thin Xls in aggregates, rarely fibrous.	Note good cleavage at 124°, silky luster, and form of Xls	Tremolite, $CaMg_3(SiO_4)_3$
Usually short thick prisms, nearly square or 8-sided, may be granular, rarely fibrous.	Shape of Xls and cleavage angles aid in its determination	Diopside, $CaMg(SiO_3)_2$
Bladed Xls, often radiating, fibrous.	Cleavage faces at an angle of 124°	Actinolite, $Ca(MgFe)_3(SiO_3)_4$
As long blade-like Xls.	Often has bluish spots in the Xls	Cyanite, Al_2SiO_5
Usually massive or as embedded grains. Xls thick and 6-sided.	Note greasy luster and poor cleavage. Never with quartz, may be with sodalite, feldspar, etc.	Nephelite, $(NaK)AlSiO_4$
Rounded grains, often with crystal faces.	Brittle. In well developed Xls or rounded grains in igneous rocks	Leucite, $KAl(SiO_3)_2$
Xls are 12-sided forms. More commonly massive or as grains.	If blue, readily recognized, otherwise told by its associates, nephelite and leucite. Never with quartz	Sodalite, Na, Al, Silicate with some chlorine.
Xls, short and thick. Granular and massive	Brittle. Two cleavages at about 90°. Commonly associated with quartz in granite. Very common feldspar	Orthoclase, $KAlSi_3O_8$
Xls fine. Cleavable to granular masses	Only the green varieties can be distinguished from orthoclase	Microcline, $KAlSi_3O_8$
Large, cleavable masses	Brittle. Often shows fine play of colors, greens, reds, blues, etc. Striated on one cleavage face	Labradorite, $CaAl_2Si_2O_8$ and $NaAlSi_3O_8$
Cleavable masses. May show fine twinning lines on one face. Massive	Often twinned so as to show striations on the cleavage faces	Albite, $NaAlSi_3O_8$
Long slender Xls, fibrous. Massive. Xls may be striated	Recognized by its peculiar yellow green color. Very characteristic	Epidote, Complex silicate of Ca, Mg, Fe, Al
Rounded green grains. Massive, granular	Brittle. Usually in basaltic rocks. Note its hardness and color	Olivine, $(MgFe)_2SiO_4$
Usually as crystals, 12 to 24 sides. May be as rounded grains. Massive	Brittle. Opaque to translucent. H. and color and shape aid in determining it	Garnet, Silicate of Ca, Mg, Al, Fe

STREAK UNCOLORED. WHITE OR LIGHT GRAY

H	Color	Streak	Cleavage & Fracture	Luster	G
HARDNESS Above 7 WILL SCRATCH GLASS					
THE FOLLOWING ARE ALL VARIETIES OF QUARTZ. NO CLEAVAGE					
7	Colorless	White	F—conchoidal to uneven	Vitreous to greasy	2.6
7	Pink	White	F—conchoidal to uneven	Vitreous to greasy	2.6
7	White and milky	White	F—conchoidal to uneven	Vitreous to greasy	2.6
7	Purple and amethystine	White	F—conchoidal to uneven	Vitreous to greasy	2.6
7	White, gray, etc.	White	F—marked conchoidal to uneven	Waxy to vitreous, dull	2.6
7	Banded, red, white, pink, brown, green, etc.	White	F—marked conchoidal to uneven	Dull to waxy to vitreous	2.6
7	Red, yellow, brown	White	F—marked conchoidal	Dull, waxy	2.6
7	Dark gray to black	White	F—marked conchoidal	Dull, waxy	2.6
7	White or light gray	White	F—marked conchoidal	Dull, waxy	2.6
7	Dark brown to nearly black	Non-colored to grayish	C—fair in one direction	Sub-vitreous to dull or resinous	3.65 3.77
7-7.5	Dark brown to green, red, pink, etc.	White	C—not good F—uneven to subconchoidal	Vitreous,	4.4 4.8
7.5-8	Green, yellow, blue, pink, etc.	White	F—conchoidal to uneven	Vitreous,	2.6 2.8
9	Gray, bluish, brown and many other colors	None	C—fair in 3 or 4 directions F—conchoidal	Vitreous to dull	3.9 4.1

TRANSMIT LIGHT ON THIN EDGES

CANNOT BE SCRATCHED BY A KNIFE

THE FOLLOWING ARE ALL VARIETIES OF QUARTZ. NO CLEAVAGE

Structure	Other Properties	Name and Composition
Usually as perfect six-sided crystals	Brittle. No cleavage. Use hardness and luster (vitreous to greasy) and F.	Rock Crystal, SiO_2
Usually as perfect six-sided crystals Also massive	Brittle. No cleavage. Use hardness and luster (vitreous to greasy) and F.	Rose Quartz, SiO_2
Massive and crystals	Brittle. No cleavage. Use hardness and luster (vitreous to greasy) and F.	Milky Quartz, SiO_2
Crystals, 6 sided. Massive	Brittle. No cleavage. Use hardness and luster (vitreous to greasy) and F. and color	Amethyst, SiO_2
Always massive	Tough. Determined by luster, fracture and toughness. Translucent	Chalcedony, SiO_2
Always massive and banded	Tough. Determined by luster, fracture and toughness. Translucent. Agate bands colored	Agate and Onyx, SiO_2
Massive and as nodules	Tough. Determined by the luster, fracture, toughness and color. Opaque	Jasper, SiO_2
Massive and as nodules	Tough. Determined by the luster, fracture, toughness and color. Opaque	Flint, SiO_2
Massive and as nodules	Tough. Determined by the luster, fracture, toughness and color. Opaque	Chert, SiO_2
Prismatic Xls. Twins, + or X shaped	Readily determined by hardness, flat Xls, and twins	Staurolite, Hydrous Fe Al silicate
Crystals, 6 sided or triangular in outline	Brittle. Xls are striated vertically. Note triangular outline if in Xls	Tourmaline, Very complex silicate
Crystals, 6 sided, columnar	Brittle. Translucent to transparent. Long Xls striated vertically. Very hard	Beryl, $Be_3Al_2(SiO_3)_6$
Usually in short 6 sided Xls. Barrel shaped	Tough to brittle. Easily determined by being harder than all other minerals	Corundum, Al_2O_3

INTRODUCTION TO ROCK TABLE

A rock may be defined as any material forming an essential part of the earth's crust. A rock is usually regarded as a hard substance and the term is generally applied to such materials, but it also embraces such soft materials as clay, mud, sand, etc. There are three great groups of rocks: **igneous** rocks, those that result from the solidification of molten material; **sedimentary** rocks, those which are deposited by water, air, and ice; **metamorphic** rocks, those produced from either of the first two by the various metamorphic processes which change the original materials either wholly or in part. The majority of the rocks found under the head of massive rocks in division III of the table are igneous rocks; divisions I and II contain the majority of the sedimentary rocks; while metamorphic rocks occur in all three of the major divisions.

The following table is designed so that the student will use the physical properties to separate the various kinds of rocks and thus lead up to the rock name. This has a tendency to prevent the use of pre-conceived ideas as to the name (which are only too often erroneous) and to cause the student to observe the real differences.

It is only attempted to bring the more common rocks into the various divisions in such a way that they may be readily separated. In using the table first determine the hardness of the rock and this will rate it in division I or II or III. Care must be exercised in this determination altho the lines between the groups are not very close. Choose a fresh portion of the rock, especially if the surface is decayed and note whether the specimen is really scratched or whether some of the minerals are merely broken. In the case of the schists and gneisses the mica is apt to be merely scratched off the specimen. Having decided on which division it is in, it should be noted whether it is in group A (massive rocks) or group B (banded rocks). Under these groups the various rocks are arranged approximately according to their hardness. This arrangement cannot be followed in Division III because the rocks are all very similar in hardness. Instead, the massive group, which is by far the largest group, is divided into sub-groups based on the size of the grains or minerals. The size of the grains and their relations to each other is what is known as texture. Once a specimen is located in a group the application of the specific tests given will soon separate the various rocks and give the proper name.

The tables do not attempt to bring together the rocks which belong to the same petrographic class. The primary object is to get a name for and learn something about the composition and physical properties of the rock.

The materials of the sandstones and conglomerates are usually cemented together or consolidated by pressure. The cements may be calcium carbonate (calcite), silica, clay, or the iron oxides, usually hematite, but also limonite. It should be noted that shales often are calcareous or they may contain some sand and sometimes considerable of the iron oxides. Limestones often contain clay or sand and this should be noted.

Note.—Acetic acid can be used in testing for calcium carbonate, but not for dolomite. Use hydrochloric acid for the latter. When using hydrochloric acid do not put more than a small drop on the rock, always putting it on a fresh surface.

GLOSSARY

Massive—uniform in color and size of grains in all directions.

Banded—shows lines or bands of different color or different mineral composition, or bedding planes.

Foliated—in bands which are more or less curved.

Porphyry—a rock which contains some crystals that are larger than the remainder, although the latter may be large enough to determine. The larger crystals are called PHENOCRYSTS. When the phenocryst is determinable its name may be used as a partial name for the rock, thus, if hornblende were the phenocryst, the rock name would be hornblende granite, or hornblende felsite, etc.

Groundmass—the fine-grained part of the rock in which the phenocrysts are embedded.

KEY TO TABLE

I. The specimen can be scratched with the finger nail.
Hardness less than 2.5 or 3..
- A. Massive. Pages 21-22.
- B. Banded. Page 22.

II. Rocks that cannot be scratched with the finger nail, but can be scratched with a knife blade. A good knife has a hardness of about 5.5.
- A. Massive. Pages 22-23.
- B. Banded. Page 23.

III. All rocks that are harder than a knife blade.
- A. Massive (1)
  1. Grained rocks. The grains over 1-16 of an inch, or determinable. Pages 23-24.
  2. Fine-grained rocks. The grains less than 1-16 of an inch, Pages 24-25.
  3. Glassy rocks. Page 25.
- B. Banded rocks. Page 25.

(1) Most of the rocks in this group may be porphyritic, that is, they may contain some mineral or minerals larger than those in the ground mass.

I. ROCKS THAT CAN BE SCRATCHED WITH THE FINGER NAIL.
A. MASSIVE.

1. Soft, friable, earthy masses, usually white, yellow, or gray. Effervesces with cold hydrochloric acid. CHALK. If it has a clayey odor when breathed upon and sticks to the tongue it is called MARL.

2. Soft, crumbly, clayey odor, sticks to tongue, sticky and plastic when wet, smooth, greasy feel when rubbed for sometime between the fingers. White, gray, yellowish, and various other colors. Breaks irregularly. CLAY.

3. White to gray, crumbly, no odor, not plastic, does not effervesce. DIATOMACEOUS EARTH.

4. White, yellow, red, grained masses. No odor, no effervesence. Sometimes fibrous or may be in transparent plates. GYPSUM.

5. Similar to 2, but harder and has compact, dull appearance. May effervesce. Breaks into chips. SHALE. (See B-2.)

6. Grained; white, red, gray, blue; has salty taste—soluble in water. ROCK SALT.

7. Friable, crumbles easily, not scratched. Colors: white, red, brown, green, yellow, etc. Grains merely broken apart and not scratched, composed of rounded or angular grains of quartz and sometimes feldspar. May effervesce. SANDSTONE. (See 11-A-6 and 7.)

8. Soft; white, gray; no odor usually, but may have; composed of various sized angular materials, such as broken minerals, rocks, pumice, etc. Porous and light, usually. TUFF.

9. White, sharp, brittle, very porous, the openings are often very large; crushed with the nail. Does not effervesce. SILICEOUS SINTER.

10. Gray or green of various shades, often dark, the light colored ones often showing a shining surface; shows no cleavage; has smooth to gritty feel; and consists of talc, some chlorite, and other materials. SOAPSTONE.

B. BANDED ROCKS. Show bedding planes or are foliated.

1. Dense; gray, white, blue, yellow, and other colors: may be finely laminated, otherwise like 2 (above). CLAY.

2. A dense rock, may be coarsely or finely laminated, otherwise like A—5 (above). SHALE.

3. Greenish; greasy feeling in foliated masses; easily cleaves into leaves that bend but do not spring back. The leaves may be small and may be mixed with other minerals. TALC-SCHIST.

4. Green to dark green, very fine grained, dense, smooth feel, shining luster, may have crystals of other minerals. CHLORITE-SCHIST.

5. Very friable and crumbles easily in the fingers. Banded. SANDSTONE. (See A—7)

6. Banded; composed mainly of mica; shiny luster on two sides of the rock; thin layers. Black, white, gray, brown, and green. **Rarely so soft.** MICA-SCHIST. (See II—B-6)

II. ROCKS HARDER THAN FINGER NAIL AND SCRATCHED WITH KNIFE.

A. MASSIVE. Do not show bands or bedding planes.

1. Has salty taste. (See I—A—6) ROCK SALT.

2. Dense, dull in appearance, clayey odor. Shell like fracture. Same as I—A—5. SHALE.

3. White, gray, pink, yellow, etc.; grained. No effervescence or odor. (See I—A—4) GYPSUM.

4. Dense to granular; shell-like to smooth fracture; usually easily scratched with knife, H—3; color: white, blue, gray, black, red, etc. Effervesces briskly with cold hydrochloric acid, may contain fossils. LIMESTONE.
When impure may have clayey odor; then called argillaceous limestone; when grained it is called MARBLE.

5. Similar to the above, except harder, about 4; heavier, and does not effervesce with cold acid unless in fine powder. Will effervesce along a scratch. May be porous. DOLOMITE.

6. Porous, brittle, does not effervesce. (See I—A—9)
SILICEOUS SINTER.

7. Grains rounded or angular, more or less cemented, with calcite, iron, clay, or silica; may effervesce; may crumble; grains mainly of quartz. Color white, red, brown, gray, etc. SANDSTONE. Same as I—A—7.

8. Similar to 6, only contains feldspar and mica. ARKOSE.

9. Composed of rounded pieces of rocks and minerals more or less firmly cemented together with clay, calcareous material, or even fine sand. Colors vary, usually depending on materials of same; grays, brown, reds, etc. The materials are larger than peas. May effervesce. CONGLOMERATE.
Sometimes the fragments are angular, it is then called a BRECCIA.

10. Angular pieces of various igneous rocks and minerals in more or less fine, ash-like material. Color: white, gray. May look like a felsite. Rarely has clayey odor. TUFF.

11. Yellowish green, dull to waxy luster, dense, smooth to splintery fracture. Hardness 2.5—5 may be harder if quartz is present. Smooth to greasy feel. SERPENTINE and SERPENTINE ROCK.

B. BANDED ROCKS OF ABOVE HARDNESS. Several of the above rocks show some kind of banding.

1. Dull, dense, splits off in chips, shell like fracture, banded, clayey odor, no effervescence. SHALE. (See I—A—5)

2. Effervesces easily with acid. H—3. See 3 above. The bands may be very fine. LIMESTONE.

3. Effervesces only along scratch, harder and heavier than 2. See 4 above—DOLOMITE.

4. Composed of grains of quartz, see 6 above. The bands may be due to different colors or mineral grains. SANDSTONE. Composed of grains of feldspar or mica, ARKOSE. See 7.

5. Dense; dull to shiny luster cleaves into thin plates which ring when struck; splintery fracture on the ends; gray, black, green, red, etc. SLATE.
As the mica becomes larger and more abundant the slate becomes PHYLLITE.

8. Contains much mica, some quartz also, cleaves irregularly. Color black, gray, white. The scales of mica **peel off easily.** May contain crystals of garnet, or other minerals. **No feldspar.** MICA SCHIST.

7. Very dark green, usually black, **shiny** luster, minerals generally long and fibrous. Hardly scratched with knife. Has appearance of a mass of needles. HORNBLENDE SCHIST.

III. ROCKS WHICH CANNOT BE SCRATCHED WITH A KNIFE BLADE OR CAN BE SCRATCHED WITH DIFFICULTY.

A. MASSIVE ROCKS.

1. GRAINED, THE GRAINS OR MINERALS EASILY DISTINGUISHED, OVER 1-16 INCH.

(a) Composed of feldspar and quartz, with or without other minerals. Color: white, gray, pink, red, or green. GRANITE. There are the following varieties:
   1. Quartz, feldspar, and biotite. BIOTITE GRANITE, also called TRUE GRANITE.
   2. Quartz, feldspar, muscovite, and biotite. MUSCOVITE—BIOTITE GRANITE.
   3. Very coarse-grained granite, crystals one inch or more in size. PEGMATITE.
   4. Medium-grained granite with large porphyritic crystals. PORPHYRITIC GRANITE.

5. Fine-grained granite with phenocrysts, or a dense rock composed of more than 50% of quartz and feldspar as phenocrysts. GRANITE PORPHYRY.

6. Quartz, feldspar, mica, and hornblende or tourmaline, etc. The last gives the rock its name, as HORNBLENDE GRANITE, TOURMALINE GRANITE, etc.

(b) Composed of feldspar with little or no quartz. Color: white, gray, shades of red. SYENITE.

1. Contains feldspar and nephelite. NEPHELITE SYENITE.
2. Contains dark feldspar, which may show twinning lines, or a play of colors, as blues, reds, greens, etc. The rock is usually dark gray. ANORTHOSITE.
3. Contains feldspar, hornblende, or mica. HORNBLENDE or MICA SYENITE.
4. Fine-grained syenite with phenocrysts, or a dense rock with more than 50% of feldspar as phenocrysts. SYENITE PORPHYRY.

(c) Rocks composed of hornblende and feldspar, or some mica. Color usually light gray. Heavy. DIORITES.

1. May be called MICA DIORITE if mica is abundant.
3. Fine-grained with phenocrysts. DIORITE PORPHYRY.

(d) Composed of a pyroxene and feldspar (usually dark). Color: usually very dark. Heavy. GABBRO.

1. Composed of feldspar, pyroxene, and olivine. OLIVINE GABBRO.
2. Composed of feldspar, pyroxene, and mica. MICA GABBRO.
3. Large crystals in dark, crystalline groundmass. GABBRO PORPHYRY. Not common.

(e) Composed of less than 50% of feldspar and some undeterminable ferromagnesian mineral. DOLERITE.

1. Phenocrysts of feldspar, hornblende, or pyroxene in a groundmass of feldspar and some undeterminable ferromagnesian mineral. DOLERITE PORPYYRY.

(f) (1) Composed of pyroxene and olivine. PERIDOTITE.
(2) Composed of pyroxene. PYROXENITE.
(3) Composed of hornblende. HORNBLENDITE.

(g) This group is more or less light colored, usually some shade of gray, green, or black.

1. Epidote and quartz or some feldspar. EPIDOTE ROCK.
2. Garnet and either ferromagnesian minerals or possibly feldspar and quartz. GARNET ROCK.

(h) Very hard and tough; minerals; all quartz; vitreous to dull luster; rounded grains may be seen cemented together; breaks through the quartz grains and not around them as in sandstone; may be banded. QUARTZITE.

2. FINE-GRAINED, DENSE ROCKS, THE MINERALS LESS THAN 1-16 INCH AND NOT RECOGNIZABLE. If a porphyry, the phenocrysts must make up less than 50% of the rock.

(a) Light colored rocks; white, red, brown, yellow, light gray, and light green. Break with more or less splintery edges. FELSITE.

1. Same but with phenocrysts (less than 50% of rock) set in a dense groundmass. The phenocrysts may be of any mineral and may give the name to the rock. FELSITE-PORPHYRY or LEUCOPHYRE.
May also say QUARTZ-FELSITE-PORPHYRY, etc.

(b) Dark colored rocks; dark gray, dark green, black. BASALT. May be porous and slaggy looking. Holes are rounded or elongated. Scoriaceous basalt.

1. Same with phenocrysts (often olivine). BASALT-PORPHYRY.

(c) Like (h) above—QUARTZITE.

(d) Dense, dark gray to nearly black, tough, has splintery to conchoidal fracture. HORNSTONE.

3. ROCKS COMPOSED WHOLLY OR IN PART OF GLASS.

1. Black, red, brownish, greenish, vitreous, conchoidal fracture. OBSIDIAN.

2. Resinous, oily or greasy luster, dull, fracture less shell-like than obsidian, generally light colored. PITCHSTONE.

3. A glassy rock full of tubular openings, usually white, and very light and porous. Often has a satiny luster. Brittle. PUMICE.

4. Either 1 or 2 may contain phenocrysts; then called a VITROPHYRE or OBSIDIAN-PORPHYRY.

B. BANDED OR FOLIATED ROCKS. These rocks may sometimes be very much crumpled and folded.

1. Composed of mica with some quartz, garnets, and other minerals. Mica may be biotite or muscovite. The mica can be scratched easily. Colors vary widely. Very shiny on the cleavage faces. Layers usually thin. MICA-SCHIST.

2. Similar to above but with excess quartz, 50% or more. QUARTZ-MICA-SCHIST.

3. Dark rock; greenish to black; consisting of long, slender crystals of hornblende. Often has fibrous appearance or radiating appearance on the surface. Bands not readily seen. HORNBLENDE-SCHIST

4. Banded rock; gneissic or foliated; usually rather coarse bands; white, red, gray, green, as rule light in color; composed of feldspar with several minerals. Several varieties are known. GNEISS.
Thus if it has the mineral composition of a granite it is called granite-gneiss; of a syenite, syenite-gneiss, etc. Or, it may contain garnets, then called GARNET-GNEISS, etc.

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